REPORT

OF THE

SEVENTIETH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

BRADFORD IN SEPTEMBER 1900.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1900.

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[*An asterisk * indicates that the title only is given. The mark † indicates the same, but with a reference to the Journal or Newspaper in which it is published* in extenso.]

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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive

gratuitously the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*; but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price. —Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee not less than two years in advance [1]; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

Class A. Permanent Members.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

Class B. Temporary Members.[2]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organising Sectional Committees.[3]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to exercise the functions of Sectional Committees until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organising Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[4] and of preparing Reports

[1] Revised by the General Committee, Liverpool, 1896.
[2] Revised, Montreal, 1884.
[3] Passed, Edinburgh, 1871, revised, Dover, 1899.
[4] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which

thereon, and on the order in which it is desirable that they should be read. The Sectional Presidents of former years are *ex officio* members of the Organising Sectional Committees.[1]

An Organising Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 2 P.M., to appoint members of the Sectional Committee.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section, who will be appointed by the General Committee at 4 P.M., and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and appoint the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, for the objects stated in the Rules of the Association. The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee except for Saturday.[5]

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the

they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed to the General Secretaries, at the office of the Association. 'For Section.........' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant General Secretary *before the conclusion of the Meeting.*

[1] Sheffield, 1879. [2] Swansea, 1880, revised, Dover, 1899.

[3] Edinburgh, 1871, revised, Dover, 1899.

[4] The meeting on Saturday is optional, Southport, 1883. [5] Nottingham, 1893

Committee of the Section, and entered on the minutes accordingly.

3. Papers which have been reported on unfavourably by the Organising Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Report. He will next proceed to read the Report of the Organising Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxix), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association, and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and*

[1] These rules were adopted by the General Committee, Plymouth, 1877.

[2] This and the following sentence were added by the General Committee, Edinburgh, 1871.

one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the Report in due time; and, further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

That it is desirable that the number of Members appointed to serve on a Committee should be as small as is consistent with its efficient working.

That a tabular list of the Committees appointed on the recommendation of each Section should be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether the several Committees appointed on the recommendation of their respective Sections had presented their reports.

That on the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee be then fixed, but that the Members to serve on such Committee be nominated and selected by the Sectional Committee at a subsequent meeting.[1]

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices regarding Grants of Money.[2]

1. No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the Rules of the Association.
2. In grants of money to Committees the Association does not contemplate the payment of personal expenses to the Members.
3. Committees to which grants of money are entrusted by the Association for the prosecution of particular Researches in Science are appointed for one year only. If the work of a Committee cannot be completed in the year, and if the Sectional Committee desire the work to be continued, application for the reappointment of the Committee for another year must be made at the next meeting of the Association.
4. Each Committee is required to present a Report, whether final or interim, at the next meeting of the Association after their appointment or reappointment. Interim Reports must be submitted in writing, though not necessarily for publication.

[1] Revised by the General Committee, Bath, 1888.
[2] Revised by the General Committee at Ipswich, 1895.

5. In each Committee the Chairman is the only person entitled to call on the Treasurer, Professor G. Carey Foster, F.R.S., for such portion of the sums granted as may from time to time be required.
6. Grants of money sanctioned at a meeting of the Association expire on June 30 following. The Treasurer is not authorised after that date to allow any claims on account of such grants.
7. The Chairman of a Committee must, before the meeting of the Association next following after the appointment or reappointment of the Committee, forward to the Treasurer a statement of the sums which have been received and expended, with vouchers. The Chairman must also return the balance of the grant, if any, which has been received and not spent; or, if further expenditure is contemplated, he must apply for leave to retain the balance.
8. When application is made for a Committee to be reappointed, and to retain the balance of a former grant which is in the hands of the Chairman, and also to receive a further grant, the amount of such further grant is to be estimated as being additional to, and not inclusive of, the balance proposed to be retained.
9. The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such report has been received.
10. Members and Committees who may be entrusted with sums of money for collecting specimens of any description are requested to reserve the specimens so obtained to be dealt with by authority of the Council.
11. Committees are requested to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus will be useful for continuing the research in question, or for other scientific purposes.
12. All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association when not employed in scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

[1] The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and of the Sectional Committee, except for Saturday.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2. To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant General Secretary.
3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

The *ex officio* members of the Committee of Recommendations are the President and Vice-Presidents of the Meeting, the General and Assistant-General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[1]

If the President of a Section is unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place, due notice of the appointment being sent to the Assistant General Secretary.[2]

[1] Passed by the General Committee at Birmingham, 1865.
[2] Passed by the General Committee at Leeds, 1890.

Corresponding Societies.[1]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Assistant General Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Assistant General Secretary of the Association, a schedule, properly filled up, which will be issued by him, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10. The Secretaries of each Section shall be instructed to transmit to

[1] Passed by the General Committee, 1884.

the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of [1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

[1] Passed by the General Committee at Belfast, 1874.

(3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year—observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of the General Committee whom they recommend for election as Members of Council.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Kelcher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.

The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.

WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbel, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.

WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., LL.D., F.R.S. L. & E. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau. Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B., M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.
SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada. BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.

SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.
SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon.M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. The Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieut. of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland. His Grace the Duke of Newcastle The Right Hon. Lord Belper. The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire. The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford. The Mayor of Oxford. Sir W. R. Anson, D.C.L., Warden of All Souls College. Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine. The Rev. B. Price, D.D., F.R.S., Sedleian Professor of Natural Philosophy. Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry.	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.
CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895.	The Most Hon. the Marquis of Bristol, M.A., Lord-Lieutenant of the County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker, F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet, Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M., B.Sc. E. P. Ridley, Esq.
SIR JOSEPH LISTER, BART., D.C.L., LL.D., President of the Royal Society LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool. The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire. Sir W. B. Forwood, J.P. Sir Henry E. Roscoe, D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Esq.

SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas.R.S., F.S.A., For.Sec.G.S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.
SIR WILLIAM CROOKES, F.R.S., V.P.C.S. BRISTOL, September 7, 1898.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Rev. the Lord Bishop of Bristol, D.D. The Right Hon. Sir Edward Fry, D.C.L., F.R.S., F.S.A. Sir F. J. Bramwell, Bart., D.C.L., LL.D., F.R.S. The Right Worshipful the Mayor of Bristol The Principal of University College, Bristol The Master of The Society of Merchant Venturers of Bristol John Beddoe, Esq., M.D., LL.D., F.R.S. Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., F.G.S.	Arthur Lee, Esq., J.P. Bertram Rogers, Esq., M.D.
PROFESSOR SIR MICHAEL FOSTER, K.C.B., M.D., D.C.L., LL.D., Sec. R.S. DOVER, September 13, 1899.	His Grace the Lord Archbishop of Canterbury, D.D. The Most Hon. the Marquis of Salisbury, K.G., M.A., D.C.L., F.R.S. The Mayor of Dover The Major-General Commanding the South-Eastern District The Right Hon. A. Akers-Douglas, M.P. The Very Rev. F. W. Farrar, D.D., F.R.S., Dean of Canterbury Sir J. Norman Lockyer, K.C.B., F.R.S. Professor G. H. Darwin, M.A., LL.D., F.R.S., Pres. R.A.S.	E. Wollaston Knocker, Esq., C.B. W. H. Pendlebury, Esq., M.A.
PROFESSOR SIR WILLIAM TURNER, M.B., D.Sc., D.C.L., LL.D., F.R.S. Bradford, September 5, 1900.	The Right Hon. the Earl of Scarbrough, Lord-Lieutenant of the West Riding of Yorkshire His Grace the Duke of Devonshire, K.G., D.C.L., LL.D., F.R.S. The Most Hon. the Marquis of Ripon, K.G., G.C.S.I., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Lord Masham His Worship the Mayor of Bradford The Hon. H. E. Butler, Lord of the Manor, Bradford Sir Alexander Binnie, M.Inst.C.E., F.G.S. Professor A. W. Rücker, M.A., D.Sc., Sec.R.S. Dr. T. E. Thorpe, Sc.D., F.R.S., Pres.C.S. Principal N. Bodington, Litt.D., Vice-Chancellor of the Victoria University Professor L. C. Miall, F.R.S.	Ramsden Bacchus, Esq. J. E. Fawcett, Esq., J.P. Frederick Stevens, Esq.

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1883–98 Sir LYON (now Lord) PLAYFAIR, F.R.S.
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1891–98 Prof. A. W. RÜCKER, F.R.S.
1898 Prof. G. C. FOSTER, F.R.S.

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1845–50 Lieut.-Colonel E. SABINE, F.R.S.
1850–52 General E. SABINE, F.R.S., and J. F. ROYLE, Esq., F.R.S.
1852–53 J. F. ROYLE, Esq., F.R.S.
1853–59 General E. SABINE, F.R.S.
1859–61 Prof. R. WALKER, F.R.S.
1861–62 W. HOPKINS, Esq., F.R.S.
1862–63 W. HOPKINS, Esq., F.R.S., and Prof. J. PHILLIPS, F.R.S.
1863–65 W. HOPKINS, Esq., F.R.S., and F. GALTON, Esq., F.R.S.
1865–66 F. GALTON, Esq., F.R.S.
1866–68 F. GALTON, Esq., F.R.S., and Dr. T. A. HIRST, F.R.S.
1868–71 Dr. T. A. HIRST, F.R.S., and Dr. T. THOMSON, F.R.S.
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1872–76 Capt. D. GALTON, F.R.S., and Dr. MICHAEL FOSTER, F.R.S.
1876–81 Capt. D. GALTON, F.R.S., and Dr. P. L. SCLATER, F.R.S.
1881–82 Capt. D. GALTON, F.R.S., and Prof. F. M. BALFOUR, F.R.S.
1882–83 Capt. DOUGLAS GALTON, F.R.S.
1883–95 Sir DOUGLAS GALTON, F.R.S., and A. G. VERNON HARCOURT, Esq., F.R.S.
1895–97 A. G. VERNON HARCOURT, Esq., F.R.S., and Prof. E. A. SCHÄFER, F.R.S.
1897–1900 Prof. SCHÄFER, F.R.S., and Sir W. C. ROBERTS-AUSTEN, F.R.S.
1900 Sir W. C. ROBERTS-AUSTEN, F.R.S., and Dr. D. H. SCOTT, F.R.S.

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1831 JOHN PHILLIPS, Esq., *Secretary*.
1832 Prof. J. D. FORBES, *Acting Secretary*.
1832–62 Prof. JOHN PHILLIPS, F.R.S.
1862–78 G. GRIFFITH, Esq., M.A.
1878–80 J. E. H. GORDON, Esq., B.A., *Assistant Secretary*.
1881 G. GRIFFITH, Esq., M.A., *Acting Secretary*.
1881–85 Prof. T. G. BONNEY, F.R.S., *Secretary*.
1885–90 A. T. ATCHISON, Esq., M.A., *Secretary*.
1890 G. GRIFFITH, Esq., M.A. *Acting Secretary*.
1890 G. GRIFFITH, Esq., M.A.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries
	MATHEMATICAL AND PHYSICAL SCIENCES.	
	COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.	
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.
	SECTION A.—MATHEMATICS AND PHYSICS.	
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton..	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S., F.R.S.E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S., F.R.S.E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.

Date and Place	Presidents	Secretaries
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S. .	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Dr. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, A. Johnson, O. J. Lodge, D. MacAlister.

Date and Place	Presidents	Secretaries
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw, H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford	Prof. A. W. Rücker, M.A., F.R.S	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich ...	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool...	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.
1897. Toronto ...	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.
1898. Bristol	Prof W. E. Ayrton, F.R.S. ...	A. P. Chattock, J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1899. Dover	Prof. J. H. Poynting, F.R.S.	J. L. Howard, C. H. Lees, W. Watson, E. T. Whittaker.
1900. Bradford ...	Dr. J. Larmor, F.R.S.	P. H. Cowell, A. Fowler, C. H. Lees, C. J. L. Wagstaffe, W. Watson, E. T. Whittaker.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope...........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, R. Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.

Date and Place	Presidents	Secretaries
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E. ...	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S.......	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S...............	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S. ...	H. S. Bell, W. Chandler Roberts, J. M. Thomson.

Date and Place	Presidents	Secretaries
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. P. Bedson, H. B. Dixon, W. R. E. Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, F.R.S.	P. P. Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	P. P. Bedson, H. B. Dixon, H. F. Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, H. Forster Morley, R. E. Moyle, W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S.	H. Forster Morley, D. H. Nagel, W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, H. Forster Morley D. H. Nagel, W. W. J. Nicol.
1891. Cardiff......	Prof. W. C. Roberts-Austen, C.B., F.R.S.	C. H. Bothamley, H. Forster Morley, W. W. J. Nicol, G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S.......	J. Gibson, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, W. W. J. Nicol.
1894. Oxford......	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

SECTION B (*continued*).—CHEMISTRY.

1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S.	Arthur Harden, C. A. Kohn
1897 Toronto ...	Prof. W. Ramsay, F.R.S.......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.
1898. Bristol......	Prof. F. R. Japp, F.R.S.	C. A. Kohn, F. W. Stoddart, T. K. Rose.
1899. Dover	Horace T. Brown, F.R.S.......	A. D. Hall, C. A. Kohn, T. K. Rose, Prof. W. P. Wynne.
1900. Bradford ...	Prof. W. H. Perkin, F.R.S. ...	W. M. Gardner, F. S. Kipping, W. J. Pope, T. K. Rose.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford......	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	J. Phillips, T. J. Torrie, Rev. J. Yates

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin......	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol......	Rev. Dr. Buckland, F.R.S.—*Geog.*, R.I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geog.*, G.B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Capt. H. M. Denham, R.N.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.

Date and Place	Presidents	Secretaries
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geog.*, G.B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork	Richard E. Griffith, F.R.S. ...	F. M. Jennings, H. E. Strickland.
1844. York	Henry Warburton, Pres. G. S.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, F.R.S.	S. Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool ..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	J. Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, G. Sanders, R. H. Scott.
1858. Leeds	William Hopkins, M.A., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, F.R.S...	Prof. Harkness, E. Hull, J. W. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S.......	E. Hull, W. Pengelly, H. Woodward.

[1] Geography was constituted a separate Section, see page lxii.

Date and Place	Presidents	Secretaries
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M.Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, F.R.S.	L.C.Miall,R.H.Tiddeman,W.Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. T. Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J.Armstrong,F.W.Rudler,W.Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, F.R.S., F.G.S....	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.........	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford......	L. Fletcher, M.A., F.R.S. ...	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S.	J. Lomas, Prof. H. A. Miers, C. Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.
1898. Bristol	W. H. Hudleston, F.R.S.	G. W. Lamplugh, Prof. H. A. Miers, H. Pentecost.
1899. Dover	Sir Arch. Geikie, F.R.S.	J. W. Gregory, G. W. Lamplugh, Capt. McDakin, Prof. H. A. Miers.
1900. Bradford ...	Prof. W. J. Sollas, F.R.S. ...	H. L. Bowman, Rev. W. Lower Carter, G. W. Lamplugh, H. W. Monckton.

Date and Place	Presidents	Secretaries

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman.......................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay.................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lxi.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lxi.

Date and Place	Presidents	Secretaries
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham [1]	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.

1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter......	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh .	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

[1] The title of Section D was changed to Biology.

Date and Place	Presidents	Secretaries
1874. Belfast......	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres.R.S.—*Dep. of Anthrop.*, Sir W.R.Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, F.R.S.—*Dep. of Anth.*, Prof. Rolleston, F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, F.R.S.—*Dep. of Anat. & Physiol.*, F. M. Balfour, F.R.S.—*Dep. of Anthropol.*, F. W. Rudler.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	R. Owen, F.R.S.—*Dep. of Anthropol.*, Prof. W.H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S.—*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport [1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal ...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen...	Prof. W. C. M'Intosh, M.D., LL.D., F.R.S. F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.

[1] Anthropology was made a separate Section, see p. lxviii.

Date and Place	Presidents	Secretaries
1888. Bath.........	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, S. J. Hickson, F. W. Oliver, H. Wager, H. Marshall Ward.
1891. Cardiff......	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[2] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W. A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY.

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S. ...	H. O. Forbes, W. Garstang, W. E. Hoyle.
1897. Toronto ...	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.
1898. Bristol......	Prof. W. F. R. Weldon, F.R.S.	Prof. R. Boyce, W. Garstang, Dr. A. J. Harrison, W. E. Hoyle.
1899. Dover	Adam Sedgwick, F.R.S.	W. Garstang, J. Graham Kerr.
1900. Bradford ...	Dr. R. H. Traquair, F.R.S. ...	W. Garstang, J. G. Kerr, T. H. Taylor, Swale Vincent.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland..................	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.

[1] Physiology was made a separate Section, see p. lxix.
[2] The title of Section D was changed to Zoology.

Date and Place	Presidents	Secretaries
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	T. K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir B. Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof.G.Rolleston,M.D.,F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S. L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D...............	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop Oliver Pembleton, Dr. W. Turner

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. lv.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. J. C. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lviii.). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lix.

Date and Place	Presidents	Secretaries
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, F. Galton, P. O'Callaghan, Dr. Norton Shaw, T. Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J.W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H.W. Bates, David Buxton, Albert J Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. O. Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I. C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.

Date and Place	Presidents	Secretaries
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff......	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford......	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich ...	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool...	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.
1897. Toronto ...	J. Scott-Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.
1898. Bristol......	Col. G. Earl Church, F.R.G.S.	H. N. Dickson, Dr. H. R. Mill, H. C. Trapnell.
1899. Dover	Sir John Murray, F.R.S.	H. N. Dickson, Dr. H. O. Forbes, Dr. H. R. Mill.
1900. Bradford...	Sir George S. Robertson, K.C.S.I.	H. N. Dickson, E. Heawood, E. R. Wethey.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin......	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork.........	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford......	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849 Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.

Date and Place	Presidents	Secretaries
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	W. Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...........	R. Birkin, jun., Prof. Leone Levi, E Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory. J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.

Date and Place	Presidents	Secretaries
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes J. E. C. Munro, G. H. Sargant.
1888. Bath.........	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff......	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford......	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1895. Ipswich ...	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool...	Rt. Hon. L. Courtney, M.P....	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1897. Toronto ...	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.
1898. Bristol... ..	J. Bonar, M.A., LL.D.	E. Cannan, Prof. A. W. Flux, H. Higgs, W. E. Tanner.
1899. Dover	H. Higgs, LL.B	A. L. Bowley, E. Cannan, Prof. A. W. Flux, Rev. G. Sarson.
1900. Bradford ...	Major P. G. Craigie, V.P.S.S.	A. L. Bowley, E. Cannan, S. J. Chapman, F. Hooper.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol......	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.......	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork.........	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York.........	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.........	Rev. W. T. Kingsley.
1846. South'mpt'n	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford......	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingh'm	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	William Cubitt, F.R.S.........	John Head, Charles Manby.
1852. Belfast......	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock. Charles Manby, James Thomson.
1853. Hull	William Fairbairn, F.R.S.	J. Oldham, J. Thomson, W. S. Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	J. Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. M. Rankine, F.R.S. ...	L. Hill, W. Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton. B. Jones, H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge.	William Fairbairn, F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle .	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, A. Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	C. Barlow, H. Bauerman. E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast......	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge H. T. Wood.
1880. Swansea ...	J. Abernethy, F.R.S.E..........	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton	John Fowler, C.E., F.G.S. ...	A. T Atchison, F Churton, H. T. Wood.
1883. Southport .	J. Brunlees, Pres. Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.

Date and Place	Presidents	Secretaries
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff......	T. Forster Brown, M.Inst.C.E.	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford......	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, P. G. M. Stoney.
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.
1897. Toronto ...	G. F. Deacon, M.Inst.C.E.	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.
1898. Bristol......	Sir J. Wolfe-Barry, K.C.B., F.R.S.	Prof. T. H. Beare, Prof. J. Munro, H. W. Pearson, W. A. Price.
1899. Dover	Sir W. White, K.C.B., F.R.S.	Prof. T. H. Beare, W. A. Price, H. E. Stilgoe.
1900. Bradford ...	Sir Alex. R. Binnie, M.Inst.C.E.	Prof. T. H. Beare, C. F. Charnock, Prof. S. Dunkerley, W. A. Price.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath.........	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas. R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff......	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford......	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.
1895. Ipswich ...	Prof. W. M. Flinders Petrie, D.C.L.	J. L. Myres, Rev. J. J. Raven, H. Ling Roth.
1896. Liverpool...	Arthur J. Evans, F.S.A.	Prof. A. C. Haddon, J. L. Myres, Prof. A. M. Paterson.
1897. Toronto ...	Sir W. Turner, F.R.S.	A. F. Chamberlain, H. O. Forbes, Prof. A. C. Haddon, J. L. Myres.

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1899. Dover	C. H. Read, F.S.A.	H. Balfour, W. H. East, Prof. A. C. Haddon, J. L. Myres.
1900. Bradford ...	Prof. John Rhys, M.A..........	Rev. E. Armitage, H. Balfour, W. Crooke, J. L. Myres.

SECTION I.—PHYSIOLOGY (including Experimental Pathology and Experimental Psychology).

1894. Oxford......	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool...	Dr. W. H. Gaskell, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington.
1897. Toronto ...	Prof. Michael Foster, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington, Dr. L. E. Shore.
1899. Dover	J. N. Langley, F.R.S.	Dr. Howden, Dr. L. E. Shore, Dr. E. H. Starling.

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1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896. Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.
1897. Toronto ...	Prof. Marshall Ward, F.R.S.	Prof. J. B. Farmer, E. C. Jeffrey, A. C. Seward, Prof. F. E. Weiss.
1898. Bristol......	Prof. F. O. Bower, F.R.S. ...	A. C. Seward, H. Wager, J. W. White.
1899. Dover	Sir George King, F.R.S.	G. Dowker, A. C. Seward, H. Wager.
1900. Bradford ...	Prof. S. H. Vines, F.R.S.......	A. C. Seward, H. Wager, W. West.

LIST OF EVENING DISCOURSES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson.....................	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S............	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).

Date and Place	Lecturer	Subject of Discourse
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.............	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn. R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath	Prof. Roscoe, F.R.S............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.

Date and Place	Lecturer	Subject of Discourse
1866. Nottingham	William Huggins, F.R.S.......	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S....	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.................	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.............	The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick.	Galvanic and Animal Electricity.
1884. Montreal...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E..........	The Great Ocean Basins.

Date and Place	Lecturer	Subject of Discourse
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
1888. Bath.........	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.........	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford......	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.
	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich ..	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.
1896. Liverpool...	Dr. F. Elgar, F.R.S.	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing
1897. Toronto ...	Prof. Roberts Austen, F.R.S.	Canada's Metals.
	J. Milne, F.R.S..................	Earthquakes and Volcanoes.
1898. Bristol......	Prof. W. J. Sollas, F.R.S. ...	Funafuti: the Study of a Coral Island.
	Herbert Jackson	Phosphorescence.
1899. Dover	Prof. Charles Richet............	La vibration nerveuse.
	Prof. J. Fleming, F.R.S.	The Centenary of the Electric Current.
1900. Bradford ...	Prof. F. Gotch, F.R.S.	Animal Electricity.
	Prof. W. Stroud.	Range Finders.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	The modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B....	A Journey through Africa.
1877. Plymouth...	W. H. Preece....................	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.........	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath.........	Sir John Lubbock, Bart., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes	Spontaneous Combustion.
1894. Oxford......	Prof. W. J. Sollas, F.R.S. ...	Geologies and Deluges.
1895. Ipswich ...	Dr. A. H. Fison	Colour.
1896. Liverpool...	Prof. J. A. Fleming, F.R.S....	The Earth a Great Magnet.
1897. Toronto ...	Dr. H. O. Forbes	New Guinea.
1898. Bristol......	Prof. E. B. Poulton, F.R.S.	The ways in which Animals Warn their enemies and Signal to their friends.
1900. Bradford ...	Prof. S. P. Thompson, F.R.S.	Electricity in the Industries.

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Vice-Presidents.—G. F. Deacon; Alexander Siemens; Sir W. H. Preece, K.C.B., F.R.S.; J. Watson.

Secretaries.—Prof. T. Hudson Beare, F.R.S.E. (*Recorder*); G. F. Charnock; Prof. S. Dunkerley, M.Sc.; W. A. Price, M.A.

SECTION H.—ANTHROPOLOGY.

President.—Prof. John Rhys, M.A.

Vice-Presidents.—J. Beddoe, M.D., F.R.S.; E. W. Brabrook, C.B., F.S.A.; Sir John Evans, K.C.B., F.R.S.; Prof. A. C. Haddon, F.R.S.; Prof. A. Macalister, F.R.S.; Prof. E. B. Tylor, F.R.S.

Secretaries.—Rev. E. Armitage, M.A.; H. Balfour, M.A.; W. Crooke, B.A.; J. L. Myres, M.A., F.S.A (*Recorder*).

SECTION K.—BOTANY.

President.—Prof. S. H. Vines, F.R.S.[1]

Vice-Presidents.—Prof. F. O. Bower, Sc.D., F.R.S.; Prof. J. Reynolds Green, F.R.S.; Dr. D. H. Scott, F.R.S.; Prof. Marshall Ward, F.R.S.

Secretaries.—A. C. Seward, F.R.S. (*Recorder*); Harold Wager; William West, F.L.S.

COMMITTEE OF RECOMMENDATIONS.

The President; the Vice-Presidents of the Meeting; the Presidents of former years; the Trustees; the General and Assistant General Secretaries; the General Treasurer.

The Presidents of the Sections.

Prof. A. R. Forsyth; C. Vernon Boys; Dr. A. A. Common; Prof. H. E. Armstrong; Dr. Horace Brown; Prof. Harold Dixon; J. J. H. Teall; J. E. Marr; Prof. S. J. Hickson; W. Garstang; E. G. Ravenstein; Dr. J. Scott Keltie; E. W. Brabrook; E. Cannan; Sir W. H. Preece; Prof. T. H. Beare; H. Balfour; Prof. A. C. Haddon; Prof. F. Gotch; Prof. Johnson Symington; Prof. F. O. Bower; Prof. Marshall Ward; Dr. D. H. Scott; Prof. E. B. Poulton.

[1] Prof. Vines was unable to attend the Meeting.

Dr. THE GENERAL TREASURER'S ACCOUNT,

1899–1900. RECEIPTS.

				£	s.	d.
Balance brought forward				1549	1	3
Life Compositions (including Transfers)				314	0	0
New Annual Members' Subscriptions				150	0	0
Annual Subscriptions				566	0	0
Sale of Associates' Tickets				538	0	0
Sale of Ladies' Tickets				120	0	0
Sale of Publications				203	8	9
Interest on Deposit at Bristol Bank				24	4	1
Dividend on Consols				200	7	4
Dividend on India 3 per Cents				104	8	0
Income Tax returned (for three years, to April 1899)				30	2	6
Unexpended Balances of Grants returned :—						
Corresponding Societies Committee	0	9	0			
Committee on Heat of Combination of Metals	2	12	0			
Ethnographical Survey Committee	11	0	0			
				14	1	0
				£3813	12	11

Investments.

	£	s.	d.
Consols	7537	3	5
India 3 per Cents	3600	0	0
	£11,137	3	5

G. CAREY FOSTER, *General Treasurer.*

from July 1, 1899, to June 30, 1900. *Cr.*

1899-1900. EXPENDITURE.

		£	s.	d.
Expenses of Dover Meeting, including Grant to Local Fund, Printing, Advertising, Payment of Clerks, &c. &c.		399	7	6
Rent and Office Expenses		51	4	4
Salaries		513	15	0
Printing, Binding, &c.		1063	9	8
Payment of Grants made at Dover	£ s. d.			
Electrical Standards	25 0 0			
Seismological Observations	60 0 0			
Radiation in a Magnetic Field	25 0 0			
Meteorological Observatory at Montreal	20 0 0			
Tables of Mathematical Functions	75 0 0			
Relation between Absorption Spectra and Constitution of Organic Bodies	30 0 0			
Wave-length Tables	5 0 0			
Electrolytic Quantitative Analysis	5 0 0			
Isomorphous Sulphonic Derivatives of Benzene	20 0 0			
The Nature of Alloys	30 0 0			
Photographs of Geological Interest	10 0 0			
Remains of Elk in the Isle of Man	5 0 0			
Pleistocene Fauna and Flora in Canada	10 0 0			
Movements of Underground Waters of Craven	40 0 0			
Table at the Zoological Station, Naples	100 0 0			
Table at the Biological Laboratory, Plymouth	20 0 0			
Index Generum et Specierum Animalium	50 0 0			
Migration of Birds	15 0 0			
Plankton and Physical Conditions of the English Channel	40 0 0			
Zoology of the Sandwich Islands	100 0 0			
Coral Reefs of the Indian Region	30 0 0			
Physical and Chemical Constants of Sea-water	100 0 0			
Future Dealings in Raw Produce	2 10 0			
Silchester Excavation	10 0 0			
Ethnological Survey of Canada	50 0 0			
New Edition of 'Anthropological Notes and Queries'	40 0 0			
Photographs of Anthropological Interest	10 0 0			
Mental and Physical Condition of Children in Schools	5 0 0			
Ethnography of the Malay Peninsula	25 0 0			
Physiological Effects of Peptone	20 0 0			
Comparative Histology of Suprarenal Capsules	20 0 0			
Comparative Histology of Cerebral Cortex	5 0 0			
Electrical Changes in Mammalian Nerves	20 0 0			
Vascular Supply of Secreting Glands	10 0 0			
Fertilisation in Phæophyceæ	20 0 0			
Corresponding Societies Committee	20 0 0			
		1072	10	0
In hands of General Treasurer:				
At Bank of England, Western Branch £758 5 11				
Less Cheques not presented 50 0 0				
	708 5 11			
Cash	5 0 6			
		713	6	5
		£3813	12	11

I have examined the above Account with the books and vouchers of the Association, and certify the same to be correct. I have also verified the balance at the Bankers', and have ascertained that the Investments are registered in the names of Lord Avebury, Lord Rayleigh, and the late Lord Playfair, transfer to the new Trustees not having yet been effected.

Approved—
D. H. SCOTT, } *Auditors.*
HORACE T. BROWN, }

W. B. KEEN, *Chartered Accountant*,
3 Church Court, Old Jewry, E.C
August 2, 1900.

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	The Earl Fitzwilliam, D.C.L.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, DD.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Asso-ciates	Ladies	Foreigners	Total			
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899
297	45	801	482	9	1915	1801 0 0	1072 10 0	1900

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting

OFFICERS AND COUNCIL, 1900–1901.

PRESIDENT.

Professor Sir William Turner, M.B., D.Sc., D.C.L., LL.D., F.R.S.

VICE-PRESIDENTS.

The Right Hon. the Earl of Scarbrough, Lord-Lieutenant of the West Riding of Yorkshire.
His Grace the Duke of Devonshire, K.G., D.C.L., LL.D., F.R.S.
The Most Hon. the Marquis of Ripon, K.G., G.C.S.I., D.C.L., F.R.S.
The Right Rev. the Lord Bishop of Ripon, D.D.
The Right Hon. Lord Masham.
His Worship the Mayor of Bradford.
The Hon. H. E. Butler, Lord of the Manor, Bradford.
Sir Alexander Binnie, M.Inst.C.E., F.G.S.
Professor A. W. Rücker, M.A., D.Sc., Sec.R.S.
Dr. T. E. Thorpe, Sc.D., F.R.S., Pres.C.S.
Principal N. Bodington, Litt.D., Vice-Chancellor of the Victoria University.
Professor L. C. Miall, F.R.S.

PRESIDENT ELECT.

Professor A. W. Rücker, M.A., D.Sc., Sec.R.S.

VICE-PRESIDENTS ELECT.

The Right Hon. the Earl of Glasgow, K.C.M.G.
The Right Hon. the Lord Blythswood.
The Right Hon. the Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S.
The Hon. the Lord Provost of Glasgow.
The Principal of the University of Glasgow.
Sir John Stirling-Maxwell, Bart., M.P.
Sir Andrew Noble, K.C.B., D.C.L., F.R.S.
Sir Archibald Geikie, D.C.L., LL.D., F.R.S.
Sir W. T. Thiselton-Dyer, K.C.M.G., C.I.E., F.R.S.
James Parker Smith, Esq., M.P.
John Inglis, Esq., LL.D.
Andrew Stewart, Esq., LL.D.

GENERAL SECRETARIES.

Professor Sir W. C. Roberts-Austen, K.C.B., D.C.L., F.R.S.
Dr. D. H. Scott, F.R.S.

ASSISTANT GENERAL SECRETARY.

G. Griffith, Esq., M.A., Harrow, Middlesex.

GENERAL TREASURER.

Professor G. Carey Foster, B.A., F.R.S., Burlington House, London, W.

LOCAL SECRETARIES FOR THE MEETING AT GLASGOW.

Sir J. D. Marwick, LL.D., F.R.S.E. | Prof. John Young, M.D. | Prof. Magnus Maclean, D.Sc.

LOCAL TREASURERS FOR THE MEETING AT GLASGOW.

Robert Gourlay, Esq., Lord Dean of Guild. | James Nicol, Esq., City Chamberlain.

ORDINARY MEMBERS OF THE COUNCIL.

Armstrong, Professor H. E., F.R.S.
Bonar, J., Esq., LL.D.
Bower, Professor F. O., F.R.S.
Callendar, Professor H. L., F.R.S.
Creak, Captain E. W., R.N., F.R.S.
Darwin, F., Esq., F.R.S.
Darwin, Major L., Sec.R.G.S.
Fremantle, Hon. Sir C. W., K.C.B.
Gaskell, Dr. W. H., F.R.S.
Halliburton, Professor W. D., F.R.S.
Harcourt, Professor L. F. Vernon, M.A.
Keltie, J. Scott, Esq., LL.D.
Lankester, Professor E. Ray, F.R.S.
Lockyer, Sir J. Norman, K.C.B., F.R.S.
Lodge, Principal O. J., F.R.S.
MacMahon, Major P. A., F.R.S.
Marr, J. E., Esq., F.R.S.
Poulton, Professor E. B., F.R.S.
Preece, Sir W. H., K.C.B., F.R.S.
Price, L. L., Esq., M.A.
Sollas, Professor W. J., F.R.S.
Thomson, Professor J. M., F.R.S.
Tilden, Professor W. A., F.R.S.
Tylor, Professor E. B., F.R.S.
Wolfe-Barry, Sir John, K.C.B., F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents an Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer an Secretaries for the ensuing Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord Avebury, D.C.L., LL.D., F.R.S., F.L.S.
The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Professor A. W. Rücker, M.A., D.Sc., Sec.R.S.

PRESIDENTS OF FORMER YEARS.

Sir Joseph D. Hooker, K.C.S.I.
Sir George Gabriel Stokes, Bart., F.R.S.
Lord Kelvin, G.C.V.O., F.R.S.
Prof. A. W. Williamson, F.R.S.
Lord Avebury, F.R.S.
Lord Rayleigh, D.C.L., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
Sir F. J. Bramwell, Bart., F.R.S.
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Sir Wm. Huggins, K.C.B., Pres.R.S.
Sir Archibald Geikie, LL.D., F.R.S.
Prof. Sir J. S. Burdon Sanderson, Bart., F.R.S.
The Marquis of Salisbury, K.G., F.R.S.
Lord Lister, D.C.L., F.R.S.
Sir John Evans, K.C.B., F.R.S.
Sir William Crookes, F.R.S.
Sir Michael Foster, K.C.B., Sec.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, Esq., F.R.S.
Prof. Sir Michael Foster, K.C.B., Sec.R.S.
G. Griffith, Esq., M.A.
P. L. Sclater, Esq., Ph.D., F.R.S.
Prof. T. G. Bonney, D.Sc., F.R.S.
Prof. A. W. Williamson, F.R.S.
A. Vernon Harcourt, Esq., F.R.S.
Prof. A. W. Rücker, Sec.R.S.
Prof. E. A. Schäfer, F.R.S.

AUDITORS.

Dr. Horace Brown, F.R.S. | E. W. Brabrook, Esq., C.B.

Report of the Council for the Year 1899–1900, *presented to the General Committee at Bradford on Wednesday, September* 5, 1900.

The Council have nominated Dr. N. Bodington, Vice-Chancellor of the Victoria University, and Professor L. C. Miall, F.R.S., Vice-Presidents for the meeting at Bradford.

The Council have nominated Professor Weldon, F.R.S., to be a Governor of the Marine Biological Association of the United Kingdom in place of the late Sir William Flower.

The Council having been informed by Professor Schäfer that he does not intend to offer himself for re-election as General Secretary after the meeting at Bradford, desire to record their sense of the valuable services which he has rendered to the Association.

The Council recommend that Dr. D. H. Scott, F.R.S., be appointed General Secretary in succession to Professor Schäfer.

The following resolutions, referred to the Council by the General Committee, have been considered and acted upon :—

(1) That in view of the opportunities of ethnographical inquiry which will be presented by the Indian Census, the Council of the Association be requested to urge the Government of India to make use of the Census Officers for the purposes enumerated below, and to place photographers at the service of the Census Officers.

1. To establish a survey of the jungle races, Bhils, Gonds, and other tribes of the central mountain districts.

2. To establish a further survey of the Naga, Kuki, and other cognate races of the Assam and Burmese frontiers.

3. To collect further information about the vagrant and criminal tribes, Haburas, Beriyas, Sansiyas, &c., in North and Central India.

4. To collect physical measurements, particularly of the various Dravidian tribes, in order to determine their origin; and of the Rajputs and Jats of Rajputana and the Eastern Panjab, to determine their relation with the Yu-echi and other Indo-Scythian races.

5. To furnish a series of photographs of typical specimens of the various races; of views of archaic industries; and of other facts interesting to ethnologists.

The Council appointed a Committee, consisting of Mr. H. Balfour, Mr. F. Galton, Professor A. C. Haddon, Mr. C. H. Read, and the General Officers, to report on this matter.

In accordance with the recommendation of the Committee, the Council requested the President to address the following letter to the Secretary of State for India :—

At the meeting of the British Association for the Advancement of Science at Dover, attention was called to the special opportunity offered by the Census about to be taken in India for collecting valuable ethnographical data concerning the races of the country; and the Council of the Association having taken the matter into consideration, and being

impressed by its scientific importance, have requested me, on their behalf, to bring to the notice of Her Majesty's Government the valuable scientific results which might be obtained by means of the Census.

The results of the Census itself constitute, of course, by their very nature, an ethnographical document of great value ; and my Council feel that, without overburdening the Officers of the Census or incurring any very large expense, that value might be increased to a very remarkable degree if to the enumeration were added the collection of some easily ascertained ethnographical data. They are encouraged to make this suggestion by the reflection that the Census Commissioner is an accomplished ethnographist, well known by his publication on the Tribes and Castes of Bengal, the valuable results of which would be supplemented by the inquiries now proposed. They feel confident that, with his aid and under his direction, most important data may be obtained at a minimum of effort and cost. I may add that should the suggestion which my Council desire to make be carried out, a great step will have been taken towards establishing a uniform method of ethnographical observation in India—a matter of great scientific importance.

Stated briefly, what my Council desire to see carried out is as follows :—

1. While collecting the ordinary information for the Census, to investigate the physical and sociological characters of the various races and tribes of India. Such data would furnish the basis for a true estimation of the number and distribution of the tribes in question, and thus powerfully contribute to a sound classification of the races of India.

Special attention to be directed (*a*) to the jungle races—Bhils, Gonds, and other tribes of the central mountain districts—concerning which our information is at present very limited.

(*b*) To the Naga, Kuki, and other cognate races of the Assam and Burmese frontiers, and of the vagrant and criminal tribes—Haburas, Beriyas, Sansiyas, &c.—in North and Central India.

(*c*) To the Dravidian tribes, and the Rajputs and Jats of Rajputana and the Eastern Panjab. This will be of service in throwing light on the important and difficult problem of the origin of these tribes and their relation with the Yu-echi and other Scythian races.

(*d*) To pay especial attention to the question of a possible Negrito element in certain ethnic groups in India.

2. To obtain, so far as can be done without too great labour and expense, a series of photographs of typical individuals of the various races, and, if it should be practicable, of views of archaic industries, &c. This, which might be accomplished by placing photographers at the service of the Census Officers, would be the commencement of an Ethnographical Survey of India similar to, and certainly no less important than, the Archæological Survey of which the Government of India may so justly be proud.

My Council, in considering the above proposal, have been assisted by a Committee of gentlemen possessing special knowledge of the subject in question, and I am to add that this Committee will be pleased to place themselves at the disposal of Her Majesty's Government to assist in the proposed investigation. If it should seem desirable to Her Majesty's Government, the Committee are pre ared to put themselves into direct

communication with the Officers of the Census, who, however, the Council have reason to believe, are fully capable of carrying out the details of the investigations proposed.

The Secretary of State for India has forwarded a copy of this letter to the Government of India for consideration.

(2) That the Council be requested to represent to Her Majesty's Government the importance of giving more prominence to Botany in the training of Indian Forest Officers.

A Committee consisting of Sir W. T. Thiselton-Dyer, Sir George King, Professor Marshall Ward, and the General Officers, was appointed to report on this matter.

As a result of their deliberations the following letter was addressed by the President to the Secretary of State for India :—

The Council of the British Association for the Advancement of Science, having had under consideration the remarks made by Sir George King at the meeting in Dover in September last, as to the deficiency in botanical knowledge of the officers in the Forest Department of India, think that the subject is one of such great importance as to justify them in bringing the conclusions at which they have arrived before the Secretary of State for India.

The Forest Department in India not only has charge of the great forests of that Empire, but is frequently called upon to supply trained officers for the care of those of our colonial possessions. It is needless to insist that those who practise the art of forestry ought to have a firm grasp of the scientific principles on which the art is based. They should be able to do more than, as a matter of routine, follow out conscientiously the rules laid down for them ; they ought to possess the scientific knowledge which will enable them to seize opportunities which may present themselves of extending the resources and developing the economic value of our forests, and which will give them power over unforeseen difficulties occasioned by plant diseases or other causes.

There seems, however, to be little doubt, from evidence which has been laid before a Committee of this Council, that, with some exceptions, the forest officers on actual duty have at most a very slender equipment of botanical knowledge. It appears that they are in many cases unable to make intelligent use, or, indeed, in individual cases, any use at all, of the excellent technical works provided for their use at the expense of India by the Secretary of State. The majority of them are unable to give scientific precision to their reports, or to demonstrate the contents of the forests under their charge to foreign experts. Indeed, probably it may be said with truth that the native subordinate officers trained in India at Dehra Dun possess a more accurate knowledge of Indian botany than do the European officers under whom they have to serve.

My Council desire to urge upon the Secretary of State for India that this undesirable state of things—undesirable for many reasons, among others that through it the capabilities of our forests are probably not as fully developed as they might be, to the detriment of Indian revenues—may be traced in part at least to the circumstances under which the forest officers are selected.

The mode of selection adopted ought to be such that the Indian Forest Service should draw into its ranks men whose aptitudes and tastes

fit them for their future duties. The work of a forest officer calls especially for those powers of observation and inference which natural-history studies are peculiarly fitted to encourage. Young men with an aptitude for such studies would seem to be material which the Secretary of State would naturally desire to secure for filling the offices in question.

But the mode of selection at present in use, so far from favouring, is distinctly antagonistic to such an end.

In the first place, the present age-limit of twenty is exercising an unfavourable influence, since it prevents the entrance into the service of men who have had a university training. Training in natural-history studies is, at present at least, very imperfectly carried out in our Public Schools, even in the best of them ; it is to our Universities and not to our Schools that we must look for young men trained in these studies ; and such men are excluded by the present age-limit. It may be worth while to point out here that some of the ablest Indian forest officers in the past have been men of university training who entered the service at a time when the age-limit was very different from what it is now.

In the second place, the examination, by means of which candidates are selected, does not tend to the selection of men of natural-history, or even of scientific, aptitude.

The examination in question is the same as that for the Indian Police Department, with the exception that German is compulsory. My Council believe that the Secretary of State for India will agree with them in thinking that a system of examination, which may be the best for the selection of officers of the Police Department, whose duties are simply administrative, cannot be expected to be the best for the selection of officers of the Forest Department, whose duties should be distinctly scientific. They therefore submit respectfully, but most earnestly, to the Secretary of State, the desirability of making some marked changes in the method of selection of candidates for the forest service in India.

They would wish in the first place to suggest to him whether it would not be possible to recruit the service, in part at least, directly from the Universities, by placing some of the vacancies at the disposal of young men who, by their university career, had given evidence of their aptitude for natural-history studies and work, and a promise of success in the application of such studies to forestry. In any case, they would urge the importance of so extending the age-limit as not to exclude men who have had a university training.

And they may here state that they understand that the candidates, who are selected from passed Students of the "Institut Agronomique" and the "École Polytechnique" for admission to the French Forest school at Nancy, must have acquired the university degree of Bachelier ès Sciences.

In the second place, they desire to urge the importance of so modifying the nature of the entrance examination as to specially adapt it to securing efficient forest officers.

The forest officer needs, in addition to other general qualifications, a knowledge of botany and an aptitude for natural-history studies. No proper grasp of botanical science can be gained without an adequate elementary knowledge of physics and chemistry. And the examination which would seem best calculated to select the fittest men for the forest service would be one in which prominence was given to botany, and to physics and chemistry as introductory to that science, with an adequate

number of marks assigned to other natural-history studies, such as geology and zoology.

If the relatively enormous value now attached to German is connected with the sending of candidates to Germany for their professional education, it must be noted that at the present day, in regard both to methods of instruction and even, to a large extent, to forest practice, France is considered by many competent judges to afford opportunities for training as good as, or possibly better than, those offered by Germany. And French ought to occupy, from this point of view, the same position as German.

In any case, what is needed by the candidate, whether he goes to Germany or to France for part of his training, is not an academic knowledge of the language but a colloquial one, such as will enable him to profit at once by a stay in the country. For the purposes of study, a knowledge of one or other tongue, though advantageous, is not necessary, since excellent and sufficient treatises and text-books are now to be found in the English language. This is shown by what my Council are told is the case, that in the French forest service examination English is now optional with German.

It may be added that if the candidates selected already possessed an adequate general acquaintance with botany and the allied sciences, there would be no need to teach these introductory and preliminary sciences at Coopers Hill. The teaching there might be limited to technical Indian botany, to forest surveying and engineering, and to the theory and practice of Forestry itself. Were this done, the stay at Coopers Hill might possibly be shortened to two years, instead of three, as at present.

In conclusion, my Council desire to state that in their opinion it is by changes in the method of selection of candidates rather than by changes in the training at Coopers Hill that amendment may be secured. They are convinced that unless some change is made in the preliminary selection of candidates, the institution at Coopers Hill cannot be expected to produce the kind of forest officers so greatly needed for the welfare of our great Indian empire. Were, however, changes made in the mode of selection, the acknowledged usefulness of Coopers Hill might be still further increased.

In the reply to this letter, dated February 27, the President was informed that the attention of the Secretary of State was drawn last autumn to the remarks in Sir George King's address at the Dover meeting, and that he has asked Sir W. Thiselton-Dyer and Sir Dietrich Brandis to be good enough to look into the matter, and to advise him in what way the Botanical teaching at Coopers Hill College can be improved and rendered more practical. The report of these authorities will be forwarded with the President's letter, for the consideration of the Government of India, and for such observations and suggestions as they may have to make, with a view to practical measures of reform.

(3) That the attention of the Council be called to the wording of the rule regarding specimens collected by Committees appointed by the Association, with a view to its revision.

The Council recommended that in the Rule referred to, viz., 'Members and Committees who may be entrusted with sums of money for collecting specimens of Natural History, are requested to reserve the specimens so

obtained to be dealt with by authority of this Association,' the words 'any description' be substituted for 'Natural History,' and 'the Council' for 'this Association.'

> (4) That the complete investigation of the Ichthyology of the West African rivers promises extremely important scientific results, and that the Council of the Association be requested to take such means as may seem to it advisable to bring the matter to the notice of the Trustees of the British Museum.

A Committee, consisting of Prof. Herdman, Prof. A. Newton, Mr. A. E. Shipley, Prof. Weldon, and the General Officers, was appointed to report on this matter.

In accordance with the recommendation of this Committee, the President, with the approval of the Council, addressed a letter to the Trustees of the British Museum explaining that the matter had been brought under the notice of the Council through an application made on behalf of Mr. Boulenger, of the British Museum, for a grant to assist a collector in obtaining fishes from the West African rivers, which application the Association had declined to accede to, not from any want of appreciation of the importance of the researches, but from the difficulties attaching to applications made to the British Association for grants in aid of researches undertaken by members of the Staff of the Natural History Museum as part of their official duties.

In reply the Director of the Natural History Departments pointed out that the application had not been made on behalf, or with the knowledge, of the Trustees, and that it was not for any work which formed part of his official duties. The small sum of money required by Mr. Boulenger for this particular occasion had, since his application to the British Association, been arranged for by the authorities of the Museum in the usual way.

The Report of the Corresponding Societies Committee for the past year, together with the list of the Corresponding Societies and the titles of the more important papers, and especially those referring to Local Scientific Investigations, published by those Societies during the year ending June 1, 1900, has been received.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Mr. W. Whitaker (*Chairman*), Dr. J. G. Garson, Sir J. Evans, Mr. J. Hopkinson, Professor R. Meldola, Professor T. G. Bonney, Mr. T. V. Holmes, Sir Cuthbert Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, Professor W. W. Watts, Rev. T. R. R. Stebbing, Mr. C. H. Read, and Mr. F. W. Rudler, is hereby nominated for reappointment by the General Committee.

The Council nominate Professor Poulton, F.R.S., Chairman, Mr. W. Whitaker, F.R.S., Vice-Chairman, and Mr. T. V. Holmes, Secretary, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Bradford.

The Council have received Reports from the General Treasurer during the past year, and his accounts from July 1, 1899, to June 30, 1900, which have been audited, are presented to the General Committee.

In accordance with the regulations the retiring Members of the Council will be :—

Professor W. A. Herdman.
Mr. W. N. Shaw.
Mr. J. J. H. Teall.
Sir W. T. Thiselton-Dyer
Sir W. H. White.

The Council recommend the re-election of the other ordinary Members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list :—

Armstrong, Professor H. E., F.R.S.
Bonar, J., Esq., LL.D.
*Bower, Professor F. O., F.R.S.
*Callendar, Professor H. L., F.R.S.
Creak, Captain E. W., R.N., F.R.S.
Darwin, F., Esq., F.R.S.
Darwin, Major L., Sec. R.G.S.
Fremantle, The Hon. Sir C. W., K.C.B.
Gaskell, Dr. W. H., F.R.S.
Halliburton, Professor W. D., F.R.S.
Harcourt, Professor L. F. Vernon, M.A., M.Inst.C.E.
Keltie, J. Scott, Esq., LL.D.
*Lankester, Professor E. Ray, F.R.S.
*Lockyer, Sir J. Norman, K.C.B. F.R.S.
Lodge, Professor Oliver, F.R.S.
MacMahon, Major P. A., F.R.S.
Marr, J. E., Esq., F.R.S.
Poulton, Professor E. B., F.R.S.
Preece, Sir W. H., K.C.B., F.R.S.
Price, L. L., Esq., M.A.
*Sollas, Professor W. J., F.R.S.
Thomson, Professor J. M., F.R.S.
Tilden, Professor W. A., F.R.S.
Tylor, Professor E. B., F.R.S.
Wolfe-Barry, Sir John, K.C.B., F.R.S.

Committees appointed by the General Committee at the Bradford Meeting in September 1900.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements. [And balance in hand.]	*Chairman.*—Lord Rayleigh. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, Oliver J. Lodge, and G. Carey Foster, Dr. A. Muirhead, Sir W. H. Preece, Professors J. D. Everett and A. Schuster, Dr. J. A. Fleming, Professors G. F. FitzGerald and J. J. Thomson, Mr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Professor J. Viriamu Jones, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. J. Rennie, Mr. E. H. Griffiths, Professors A. W. Rücker, H. L. Callendar, and Sir W. C. Roberts-Austen, and Mr. G. Matthey.	45 0 0
Seismological Observations.	*Chairman.*—Prof. J. W. Judd. *Secretary.*—Professor J. Milne. Lord Kelvin, Professor T. G. Bonney, Mr. C. V. Boys, Professor G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Professor J. A. Ewing, Professor C. G. Knott, Professor R. Meldola, Mr. R. D. Oldham, Professor J. Perry, Mr. W. E. Plummer, Professor J. H. Poynting, Mr. Clement Reid, Mr. Nelson Richardson, and Professor H. H. Turner.	75 0 0
To consider the most suitable Method of Determining the Components of the Magnetic Force on board Ship.	*Chairman.* — Professor A. W. Rücker. *Secretary.*—Dr. C. H. Lees. Lord Kelvin, Professor A. Schuster, Captain Creak, Professor W. Stroud, Mr. C. V. Boys, and Mr. W. Watson.	10 0 0
The relation between the Absorption Spectra and Chemical Constitution of Organic Substances. [6*l.* 8*s.* 9*d.* in hand.]	*Chairman* and *Secretary.*—Professor W. Noel Hartley. Professor F. R. Japp, Professor J. J. Dobbie, and Mr. Alexander Lauder.	—

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Sir J. N. Lockyer, Professors J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, and Sir W. de W. Abney.	5 0 0
The Study of Isomorphous Sulphonic Derivatives of Benzene.	*Chairman.*—Professor H. A. Miers. *Secretary.*—Professor H. E. Armstrong. Dr. W. P. Wynne, and Mr. W. J. Pope.	35 0 0
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation. [6*l.* in hand.]	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Prof. P. F. Kendall. Professor T. G. Bonney, Mr. C. E. De Rance, Professor W. J. Sollas, Mr. R. H. Tiddeman, Rev. S. N. Harrison, Mr. J. Horne, Mr. Dugald Bell, Mr. F. M. Burton, Mr. J. Lomas, Mr. A. R. Dwerryhouse, Mr. J. W. Stather, Mr. W. T. Tucker, and Mr. F. W. Harmer.	—
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest. [10*l.* in hand.]	*Chairman.*—Professor J. Geikie. *Secretary.*—Professor W. W. Watts. Professor T. G. Bonney, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, R. Kidston, J. J. H. Teall, J. G. Goodchild, H. Coates, C. V. Crook, G. Bingley, and R. Welch.	—
To study Life-zones in the British Carboniferous Rocks.	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Dr. Wheelton Hind. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Mr. E. J. Garwood, Dr. G. J. Hinde, Professor P. F. Kendall, Mr. J. W. Kirkby, Mr. R. Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Mr. B. N. Peach, Mr. A. Strahan, and Dr. H. Woodward.	20 0 0
The Excavation of the Ossiferous Caves at Uphill, near Weston-super-Mare.	*Chairman.*—Professor C. Lloyd Morgan. *Secretary.*—Mr. H. Bolton. Professor W. Boyd Dawkins, Mr. W. R. Barker, Mr. S. H. Reynolds, and Mr. E. T. Newton.	5 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
The movements of Underground Waters of North-west Yorkshire.	*Chairman.*—Professor W. W. Watts. *Secretary.*—Captain A. R. Dwerryhouse. Professor A. Smithells, Rev. E. Jones, Mr. Walter Morrison, Mr. G. Bray, Mr. W. Lower Carter, Mr. W. Fairley, Professor P. F. Kendall, and Mr. J. E. Marr.	50 0 0
To explore Irish Caves. [Collections to be placed in the Science and Art Museum, Dublin.]	*Chairman.*—Dr. R. F. Scharff. *Secretary.*—Mr. R. Lloyd Praeger. Mr. G. Coffey, Professor Grenville Cole, Dr. Cunningham, Mr. A. McHenry, and Mr. R. J. Ussher.	15 0 0
To enable Mr. H. H. Stewart to work at the Annelids, and to aid other competent investigator, to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor G. B. Howes. Professor E. Ray Lankester, Professor W. F. R. Weldon, Professor S. J. Hickson, Mr. A. Sedgwick, and Professor W. C. McIntosh.	100 0 0
To enable Mr. R. C. Punnett to continue his investigations on the pelvic plexus of Elasmobranch fishes, and to enable other competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman.*—Mr. G. C. Bourne. *Secretary.*—Mr. W. Garstang. Professor E. Ray Lankester, Professor Sydney H. Vines, Mr. A. Sedgwick, and Professor W. F. R. Weldon.	20 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Mr. R. McLachlan, and Mr. W. E. Hoyle.	75 0 0
To work out the details of the Observations on the Migration of Birds at Lighthouses and Lightships, 1880–87.	*Chairman.*—Professor A. Newton. *Secretary.*—Rev. E. P. Knubley. Mr. John A. Harvie-Brown, Mr. R. M. Barrington, and Mr. A. H. Evans.	10 0 0
Terrestrial Surface-waves and Wave-like Surfaces.	*Chairman.*—Dr. Scott Keltie. *Secretary.*—Colonel F. Bailey. Mr. Vaughan Cornish, Mr. A. R. Hunt, and Mr. W. H. Wheeler.	5 0 0
Changes of the Land-level of the Phlegræan Fields.	*Chairman.*—Dr. H. R. Mill. *Secretary.*—Mr. H. N. Dickson. Dr. Scott Keltie, and Mr. R. T. Günther.	50 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
State Monopolies in other Countries. [Balance of grant unexpended, 13*l.* 13*s.* 6*d.*]	*Chairman.*—Sir Robert Giffen. *Secretary.*—Mr. H. Higgs. Mr. W. M. Acworth, the Rt. Hon. L. H. Courtney, and Professor H. S. Foxwell.	—
The Economic Effect of Legislation regulating Women's Labour.	*Chairman.*—Mr. E. W. Brabrook. *Secretary.*—Mr. A. L. Bowley. Professor Edgeworth, Professor Smart, Professor Flux, Mr. S. J. Chapman, Mr. L. L. Price, and Mrs. J. R. MacDonald.	15 0 0
To consider means by which better practical effect can be given to the Introduction of the Screw Gauge proposed by the Association in 1884. [And balance in hand.]	*Chairman.*—Sir W. H. Preece. *Secretary.*—Mr. W. A. Price. Lord Kelvin, Sir F. J. Bramwell, Sir H. Trueman Wood, Maj.-Gen. Webber, Mr. R. E. Crompton, Mr. A. Stroh, Mr. A. Le Neve Foster, Mr. C. J. Hewitt, Mr. G. K. B. Elphinstone, Col. Watkin, Mr. E. Rigg, Mr. Vernon Boys, and Mr. J. M. Gorham.	45 0 0
To investigate the resistance of Road Vehicles to Traction.	*Chairman.*—Sir Alexander Binnie. *Secretary.*—Professor H. S. Hele Shaw. Mr. W. W. Beaumont, Sir D. Salomans, Mr. J. Brown, Mr. H. Maclaren, Mr. Aveling, Mr. W. H. Wheeler, and Professor T. Hudson Beare.	75 0 0
To co-operate with the Silchester Excavation Fund Committee in their explorations.	*Chairman.*—Mr. A. J. Evans. *Secretary.*—Mr. John L. Myres. Mr. E. W. Brabrook.	10 0 0
To organise an Ethnological Survey of Canada.	*Chairman.*—Professor D. P. Penhallow. *Secretary.*—Dr. George Dawson. Mr. E. W. Brabrook, Professor A. C. Haddon, Mr. E. S. Hartland, Sir J. G. Bourinot, Mr. B. Sulte, Mr. C. Hill-Tout, Mr. David Boyle, Mr. C. N. Bell, Professor E. B. Tylor, Professor J. Mavor, Mr. C. F. Hunter, and Dr. W. F. Ganong.	30 0 0
To conduct Explorations with the object of ascertaining the age of Stone Circles. [Balance in hand.]	*Chairman.*—Dr. J. G. Garson. *Secretary.*—Mr. H. Balfour. Sir John Evans, Mr. C. H. Read, Professor Meldola, Mr. A. J. Evans, Dr. R. Munro, and Professor Boyd-Dawkins.	—

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest. [Balance in hand.]	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. J. L. Myres. Dr. J. G. Garson, Mr. H. Ling Roth, Mr. H. Balfour, Mr. E. S. Hartland, and Professor Flinders Petrie.	—
The Present State of Anthropological Teaching in the United Kingdom and Elsewhere.	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Mr. H. Ling Roth. Professor A. Macalister, Professor A. C. Haddon, Mr. C. H. Read, Mr. H. Balfour, Mr. F. W. Rudler, Dr. R. Munro, and Professor Flinders Petrie.	5 0 0
To conduct Explorations in Crete.	*Chairman.*—Sir John Evans. *Secretary.*—Mr. J. L. Myres. Mr. A. J. Evans, Mr. D. J. G. Hogarth, Professor A. Macalister, and Professor W. Ridgeway.	145 0 0
The Physiological Effects of Peptone and its Precursors when introduced into the circulation.	*Chairman.* — Professor E. A. Schäfer. *Secretary.* — Professor W. H. Thompson. Professor R. Boyce and Professor C. S. Sherrington.	30 0 0
The Chemistry of Bone Marrow.	*Chairman.* — Professor E. A. Schäfer. *Secretary.*—Mr. W. R. Hutchison. Dr. Leonard Hill and Professor F. Gotch.	15 0 0
The Development of the Suprarenal Capsules in the Rabbit.	*Chairman.*—Professor E. H. Starling. *Secretary*—Mr. Swale Vincent. Mr. Victor Horsley.	5 0 0
Fertilisation in Phæophyceæ.	*Chairman.*—Professor J. B. Farmer. *Secretary.*—Professor R. W. Phillips. Professor F. O. Bower, and Professor Harvey Gibson.	15 0 0
Morphology, Ecology, and Taxonomy of the Podostemaceæ.	*Chairman.*—Prof. Marshall Ward. *Secretary.*—Prof. J. B. Farmer. Professor F. O. Bower.	20 0 0
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Professor R. Meldola, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Sir Cuthbert E. Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, Professor W. W. Watts, Rev. T. R. R. Stebbing, Mr. C. H. Read, and Mr. F. W. Rudler.	15 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
Radiation from a Source of Light in a Magnetic Field.	*Chairman.*—Professor G. F. FitzGerald. *Secretary.*—Mr. W. E. Thrift. Professor A. Schuster, Professor O. J. Lodge, Professor S. P. Thompson, Dr. Gerald Molloy, and Dr. W. E. Adeney.
To establish a Meteorological Observatory on Mount Royal, Montreal.	*Chairman.*—Professor H. L. Callendar. *Secretary.*—Professor C. H. McLeod. Professor F. Adams, and Mr. R. F. Stupart.
For calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form.	*Chairman.*—Lord Kelvin. *Secretary.*—Lieut.-Colonel Allan Cunningham. Dr. J. W. L. Glaisher, Professor A. G. Greenhill, Professor W. M. Hicks, Major P. A. MacMahon, and Professor A. Lodge.
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Sir John Murray, Dr. A. Buchan, and Professor R. Copeland.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Dr. C. Chree. Lord Kelvin, Professor G. H. Darwin, Professor G. Chrystal, Professor A. Schuster, Captain E. W. Creak, the Astronomer Royal, Mr. William Ellis, and Professor A. W. Rücker.
The Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water.	*Chairman.*—Professor J. D. Everett. *Secretary.*—Professor J. D. Everett. Lord Kelvin, Sir Archibald Geikie, Mr. James Glaisher, Professor Edward Hull, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, Professor Michie Smith, and Professor H. L. Callendar.
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Dr. G. Johnstone Stoney. *Secretary.*—Professor H. McLeod. Sir G. G. Stokes, Professor A. Schuster, Sir H. E. Roscoe, Captain Sir W. de W. Abney, Dr. C. Chree, Professor G. F. FitzGerald, Professor H. L. Callendar, Mr. W. E. Wilson, and Mr. A. A. Rambaut.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
That Miss Hardcastle be requested to draw up a Report on the present state of the Theory of Point-Groups.	—
The Nature of Alloys.	*Chairman and Secretary.*—Mr. F. H. Neville. Mr. C. T. Heycock and Mr. E. H. Griffiths.
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. McLeod. *Secretary.*—Sir W. C. Roberts-Austen. Mr. H. G. Madan and Mr. D. H. Nagel.
The Teaching of Natural Science in Elementary Schools.	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Lord Avebury, Mr. George Gladstone, Mr. W. R. Dunstan, Sir Philip Magnus, Sir H. E. Roscoe, Dr. Silvanus P. Thompson, and Professor A. Smithells.
That Mr. Alfred Harker be requested to prepare a Report on the constitution of Igneous and Metamorphic Rocks.	—
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.
To consider the best Methods for the Registration of all Type Specimens of Fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, Professor H. G. Seeley, Mr. H. Woods, and Rev. J. F. Blake.
The Collection, Preservation, and Systematic Registration of Canadian Photographs of Geological Interest.	*Chairman.*—Professor A. P. Coleman. *Secretary.*—Mr. Parks. Professor A. B. Willmott, Professor F. D. Adams, Mr. J. B. Tyrrell, and Professor W. W. Watts.
To report upon the Present State of our Knowledge of the Structure of Crystals.	*Chairman.*—Professor N. Story Maskelyne. *Secretary.*—Professor H. A. Miers. Mr. L Fletcher, Professor W. J. Sollas, Mr. W. Barlow, Mr. G. F. H. Smith, and the Earl of Berkeley.
To examine the Conditions under which remains of the Irish Elk are found in the Isle of Man.	*Chairman.*—Professor W. Boyd Dawkins. *Secretary.*—Mr. P. M. C. Kermode. Mr. G. W. Lamplugh, Canon E. B. Savage, and Rev. S. N. Harrison.
The Periodic Investigation of the Plankton and Physical Conditions of the English Channel.	*Chairman.*—Professor E. Ray Lankester. *Secretary.*—Mr. Walter Garstang. Professor W. A. Herdman, and Mr. H. N. Dickson.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose.	Members of the Committee.
To continue the investigation of the Zoology of the Sandwich Islands, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government or the Trustees of the Museum at Honolulu. The Committee to have power to dispose of specimens where advisable.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Professor S. J. Hickson, Dr. P. L. Sclater, Mr. F. Du Cane Godman, and Mr. Edgar A. Smith.
To investigate the structure, formation, and growth of the Coral Reefs of the Indian Region, with special observations on the inter-relationship of the reef organisms, the depths at which they grow, the food of corals, effects of currents and character of the ocean bottom, &c. The land flora and fauna will be collected, and it is intended that observations shall be made on the manners, &c., of the natives in the different parts of the Maldive group.	*Chairman.*—Mr. A. Sedgwick. *Secretary.*—J. Graham Kerr. Professor J. W. Judd, Mr. J. J. Lister, and Mr. S. F. Harmer.
To promote the Systematic Collection of Photographic and other Records of Pedigree Stock.	*Chairman.*—Mr. Francis Galton. *Secretary.*—Professor W. F. R. Weldon.
Climatology of Tropical Africa.	*Chairman.*—Mr. E. G. Ravenstein. *Secretary.*—Mr. H. N. Dickson. Sir John Kirk and Dr. H. R. Mill.
To draw up a Scheme for a Systematic Survey of British Protectorates.	*Chairman.*—Sir T. H. Holdich. *Secretary.*—H. N. Dickson. Col. Sir W. Everett, Col. D. A. Johnston, and E. G. Ravenstein.
To examine the Natural History and Ethnography of the Malay Peninsula.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. W. Crooke. Professor A. Macalister, and Professor W. Ridgeway.
The Lake Village at Glastonbury.	*Chairman.*—Dr. R. Munro. *Secretary.*—Mr. A. Bulleid. Professor W. Boyd Dawkins, Sir John Evans, Mr. Arthur J. Evans, and Mr. C. H. Read.
The Micro-chemistry of Cells.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor A. B. Macallum. Professor E. Ray Lankester, Professor W. D. Halliburton, Mr. G. C. Bourne, and Professor J. J. Mackenzie.

Communications ordered to be printed in extenso.

The Report on the Chemical Compounds contained in Alloys, by F. H. Neville, F.R.S.

The Report on the Constitution of Camphor, by A. Lapworth, D.Sc.

The Paper on the Age of the Earth, by Professor J. Joly, F.R.S.

Alteration of the Title of a Section.

That the title of Section G be altered from 'Mechanical Science' to 'Engineering.'

Women to be eligible for admission to Committees.

That in future Women Members of the Association shall be eligible for the General and Sectional Committees.

Resolutions referred to the Council for consideration, and action if desirable.

That in connection with the Resolution relating to the admission of women to Committees, as well as on general grounds, the Council be requested to reconsider the present mode of electing members of Sectional Committees.

That the Council be requested to consider the appointment of a separate Section for Education.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Bradford Meeting, September, 1900. The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.

Mathematics and Physics.

	£	s.	d.
*Rayleigh, Lord—Electrical Standards (balance in hand and)	45	0	0
*Judd, Professor J. W.—Seismological Observations	75	0	0
*Rücker, Professor A. W.—Magnetic Force on board Ship (renewed)	10	0	0
Chemistry.			
*Hartley, Professor W. N.—Relation between Absorption Spectra and Constitution of Organic Substances (£6 8*s.* 9*d.* in hand)	—		
*Roscoe, Sir H. E.—Wave-length Tables	5	0	0
*Miers, Professor H. A.—Isomorphous Sulphonic Derivatives of Benzene	35	0	0
Geology.			
*Marr, Mr. J. E.—Erratic Blocks (£6 in hand)	—		
*Geikie, Professor J.—Photographs of Geological Interest (£10 in hand)	—		
*Marr, Mr. J. E.—Life-zones in British Carboniferous Rocks	20	0	0
*Lloyd-Morgan, Professor C.—Ossiferous Caves at Uphill (renewed)	5	0	0
*Watts, Professor W. W.—Underground Water of North-west Yorkshire	50	0	0
*Scharff, Dr.—Exploration of Irish Caves (renewed)	15	0	0
Zoology.			
*Herdman, Professor W. A.—Table at the Zoological Station, Naples	100	0	0
*Bourne, Mr. G. C.—Table at the Biological Laboratory, Plymouth	20	0	0
*Woodward, Dr. H.—Index Generum et Specierum Animalium	75	0	0
*Newton, Professor A.—Migration of Birds	10	0	0
Geography.			
Keltie, Dr. J. Scott—Terrestrial Surface Waves	5	0	0
Mill, Dr. H. R.—Changes of Land-level in the Phlegræan Fields	50	0	0
Economic Science and Statistics.			
*Giffen, Sir R.—State Monopolies in other Countries (£13 13*s.* 6*d.* in hand)	—		
Brabrook, E. W.—Legislation regulating Women's Labour	15	0	0
Carried forward	535	0	0

* Reappointed.

	£	s.	d.
Brought forward	535	0	0
Mechanical Science.			
*Preece, Sir W. H.—Small Screw Gauge (balance in hand and)	45	0	0
Binnie, Sir A.—Resistance of Road Vehicles to Traction ...	75	0	0
Anthropology.			
*Evans, Mr. A. J.—Silchester Excavation	10	0	0
*Penhallow, Professor D. P.—Ethnological Survey of Canada	30	0	0
*Garson, Dr. J. G.—Age of Stone Circles (balance in hand)...	—		
*Read, Mr. C. H.—Photographs of Anthropological Interest (£10 in hand)	—		
*Tylor, Professor E. B.—Anthropological Teaching	5	0	0
Evans, Sir John—Exploration in Crete	145	0	0
Physiology.			
*Schäfer, Professor E. A.—Physiological Effects of Peptone...	30	0	0
Schäfer, Professor E. A.—Chemistry of Bone Marrow	15	0	0
Starling, Professor E. H.—Suprarenal Capsules in the Rabbit	5	0	0
Botany.			
*Farmer, Professor J. B.—Fertilisation in Phæophyceæ	15	0	0
Marshall Ward, Professor—Morphology, Ecology, and Taxonomy of Podostemaceæ	20	0	0
Corresponding Societies.			
*Whitaker, Mr. W.—Preparation of Report	15	0	0
	£945	0	0

* Reappointed.

The Annual Meeting in 1901.

The Annual Meeting of the Association in 1901 will be held at Glasgow, commencing on September 11.

The Annual Meeting in 1902.

The Annual Meeting of the Association in 1902 will be held at Belfast.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars in Lacaille	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Firth of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland ...	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells ...	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology.........1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu......	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals......	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh.................	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces...	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall .	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York............	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay............................	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers..........................	11	7	6
Anemometers' Repairs.........	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854 £75 0 0; 1855 £500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seed	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging, Shetland	75	0	0
Dredging, Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl Series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall..	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorology	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Naples Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acid in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Electricity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record	100	0	0
Investigation of Pulse Phenomena by means of Siphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters	15	0	0
Transmission of Electrical Impulses through Nerve Structure	30	0	0
Calculation of Factor Table for 4th Million	100	0	0
Anthropometric Committee	66	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature ...	20	0	0
Electrical Standards	25	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station ...	50	0	0
Naples Zoological Station ...	75	0	0
Natural History of Socotra ...	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe ...	25	0	0
Circulation of Underground Waters	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra ...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee ...	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters	15	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station ...	25	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Exploration of Mount Kilima-njaro	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Meteorological Observatory at Chepstow	25	0	0
Tidal Observations	10	0	0
Ultra Violet Spark Spectra ...	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa	10	0	0
Erratic Blocks of England ...	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds	20	0	0
Coagulation of Blood	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee ...	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station	100	0	0
Zoological Literature Record	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Granton Biological Station	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.

	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record	100	0	0
Granton Biological Station	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.

	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Cae Gwyn Cave, N. Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	75	0	0
Electrolysis	20	0	0
Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations	100	0	0
Flora of China	25	0	0
Naples Zoological Station	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands	100	0	0
Geology and Geography of Atlas Range	100	0	0
Action of Waves and Currents in Estuaries	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northampton	25	0	0
Botanical Station at Peradeniya	25	0	0

	£	s.	d.
Experiments with a Tow-net	4	3	9
Naples Zoological Station	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North - Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North - Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Observations on Ben Nevis	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0

	£	s.	d.
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

	£	s.	d.
Electrical Standards............	25	0	0
Photographs of Meteorological Phenomena.....................	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills............................	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth-tremors	50	0	0
Exploration of Calf-Hole Cave.....	5	0	0
Naples Zoological Station ...	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart............	10	0	0
Exploration in Abyssinia ...	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics.......................	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury............................	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children..............	20	0	0
Corresponding Societies	25	0	0
	£583	15	6

1895.

	£	s.	d.
Electrical Standards............	25	0	0
Photographs of Meteorological Phenomena.....................	10	0	0
Earth Tremors , ...	75	0	0
Abstracts of Physical Papers	100	0	0
Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Standards	25	0	0
Meteorological Observations on Ben Nevis	50	0	0
Wave-length Tables of the Spectra of the Elements ...	10	0	0
Action of Light upon Dyed Colours	4	6	1
Formation of Haloids from Pure Materials	20	0	0
Isomeric Naphthalene Derivatives..........................	30	0	0
Electrolytic Quantitative Analysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Photographs of Geological Interest	10	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills......................	3	0	0
New Sections of Stonesfield Slate	50	0	0
Exploration of Calf Hole Cave	10	0	0
Nature and Probable Age of High-level Flint-drifts	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea............ ..	35	9	4
Zoology and Botany of the West India Islands	50	0	0
Index of Genera and Species of Animals	50	0	0
Climatology of Tropical Africa	5	0	0
Exploration of Hadramut ...	50	0	0
Calibration and Comparison of Measuring Instruments ...	25	0	0
Anthropometric Measurements in Schools	5	0	0
Lake Village at Glastonbury	30	0	0
Exploration of a Kitchen-midden at Hastings	10	0	0
Ethnographical Survey	10	0	0
Physiological Applications of the Phonograph...............	25	0	0
Corresponding Societies	30	0	0
	£977	15	5

1896.

	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	2	6	1
Electrolytic Quantitative Analysis	10	0	0
The Carbohydrates of Barley Straw	50	0	0
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
Investigation of a Coral Reef by Boring and Sounding	10	0	0
Examination of Locality where the Cetiosaurus in the Oxford Museum was found	25	0	0
Palæolithic Deposits at Hoxne	25	0	0
Fauna of Singapore Caves	40	0	0
Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North-Western Tribes of Canada	100	0	0
Lake Village at Glastonbury	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1,104	6	1

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electrochemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0
Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£1,059	10	8

1898.

	£	s.	d.
Electrical Standards	75	0	0
Seismological Observations	75	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electro-chemistry	35	0	0
Meteorological Observatory at Montreal	50	0	0

	£	s.	d.
Wave-length Tables of the Spectra of the Elements ...	20	0	0
Action of Light upon Dyed Colours	8	0	0
Erratic Blocks	5	0	0
Investigation of a Coral Reef	40	0	0
Photographs of Geological Interest	10	0	0
Life-zones in British Carboniferous Rocks..................	15	0	0
Pleistocene Fauna and Flora in Canada	20	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	14	0	0
Index Generum et Specierum Animalium	100	0	0
Healthy and Unhealthy Oysters	30	0	0
Climatology of Tropical Africa	10	0	0
State Monopolies in other Countries	15	0	0
Small Screw Gauge	20	0	0
North-Western Tribes of Canada........	75	0	0
Lake Village at Glastonbury	37	10	0
Silchester Excavation	7	10	0
Ethnological Survey of Canada	75	0	0
Anthropology and Natural History of Torres Straits...	125	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies Committee	25	0	0
	£1,212	0	0

1899.

	£	s.	d.
Electrical Standards............	225	0	0
Seismological Observations ...	65	14	8
Science Abstracts	100	0	0
Heat of Combination of Metals in Alloys	20	0	0
Radiation in a Magnetic Field	50	0	0
Calculation of Certain Integrals	10	0	0
Action of Light upon Dyed Colours	4	19	6
Relation between Absorption Spectra and Constitution of Organic Substances	50	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	10	0	0
Remains of Irish Elk in the Isle of Man....................	15	0	0
Pleistocene Flora and Fauna in Canada	30	0	0
Records of Disappearing Drift Section at Moel Tryfaen ...	5	0	0
Ty Newydd Caves..............	40	0	0
Ossiferous Caves at Uphill ...	30	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Apparatus for Keeping Aquatic Organisms under Definite Physical Conditions	15	0	0
Plankton and Physical Conditions of the English Channel during 1899	100	0	0
Exploration of Sokotra	35	0	0
Lake Village at Glastonbury	50	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	35	0	0
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Age of Stone Circles...........	20	0	0
Physiological Effects of Peptone	30	0	0
Electrical Changes accompanying Discharge of Respiratory Centres..............	20	0	0
Influence of Drugs upon the Vascular Nervous System...	10	0	0
Histological Changes in Nerve Cells..........................	20	0	0
Micro-chemistry of Cells	40	0	0
Histology of Suprarenal Capsules	20	0	0
Comparative Histology of Cerebral Cortex	10	0	0
Fertilisation in Phyæophyceæ	20	0	0
Assimilation in Plants	20	0	0
Zoological and Botanical Publication	5	0	0
Corresponding Societies Committee	25	0	0
	£1,430	14	2

1900.

	£	s.	d.
Electrical Standards............	25	0	0
Seismological Observations...	60	0	0
Radiation in a Magnetic Field	25	0	0
Meteorological Observatory at Montreal........................	20	0	0
Tables of Mathematical Functions	75	0	0
Relation between Absorption Spectra and Constitution of Organic Bodies	30	0	0
Wave-length Tables	5	0	0
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Vascular Supply of Secreting Glands	10	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresp. Societies Committee	20	0	0
	£1,072	10	0

General Meetings.

On Wednesday, September 5, at 8.30 P.M., in St. George's Hall, Bradford, Sir Michael Foster, K.C.B., Sec.R.S. (represented by Sir Henry E. Roscoe, F.R.S.), resigned the office of President to Sir William Turner, D.C.L., F.R.S., who took the Chair, and delivered an Address, for which see page 3.

On Thursday, September 6, at 8.30 P.M., a Soirée took place in St. George's Hall.

On Friday, September 7, at 8.30 P.M., in St. George's Hall, Professor Francis Gotch, F.R.S., delivered a discourse on 'Animal Electricity.'

On Monday, September 10, at 8.30 P.M., in St. George's Hall, Professor W. Stroud delivered a discourse on 'Range Finders.'

On Tuesday, September 11, at 8.30 P.M., a Soirée took place in St. George's Hall.

On Wednesday, September 12, at 2.30 P.M., in the Mechanics' Institute, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to Glasgow. [The Meeting is appointed to commence on Wednesday, September 11, 1901.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

PROFESSOR SIR WILLIAM TURNER, M.B., D.C.L., LL.D., D.Sc., F.R.S.,

PRESIDENT.

TWENTY-SEVEN years ago the British Association met in Bradford, not at that time raised to the dignity of a City. The meeting was very successful, and was attended by nearly 2,000 persons—a forecast, let us hope, of what we may expect at the present assembly. An eminent chemist, Professor A. W. Williamson, presided. On this occasion the Association has selected for the presidential chair one whose attention has been given to the study of an important department of biological science. His claim to occupy, however unworthily, the distinguished position in which he has been placed, rests, doubtless, on the fact that, in the midst of the engrossing duties devolving on a teacher in a great University and School of Medicine, he has endeavoured to contribute to the sum of knowledge of the science which he professes. It is a matter of satisfaction to feel that the success of a meeting of this kind does not rest upon the shoulders of the occupant of the presidential chair, but is due to the eminence and active co-operation of the men of science who either preside over or engage in the work of the nine or ten sections into which the Association is divided, and to the energy and ability for organisation displayed by the local Secretaries and Committees. The programme prepared by the general and local officers of the Association shows that no efforts have been spared to provide an ample bill of fare, both in its scientific and social aspects. Members and Associates will, I feel sure, take away from the Bradford Meeting as pleasant memories as did our colleagues of the corresponding Association Française, when, in friendly collaboration at Dover last year, they testified to the common citizenship of the Universal Republic of Science. As befits a leading centre of industry in the great county of York, the applications of science to the industrial arts and to agriculture will form subjects of discussion in the papers to be read at the meeting.

Since the Association was at Dover a year ago, two of its former Presidents have joined the majority. The Duke of Argyll presided at the meeting in Glasgow so far back as 1855. Throughout his long and energetic life, he proved himself to be an eloquent and earnest speaker, one who gave to the consideration of public affairs a mind of singular independence, and a thinker and writer in a wide range of human knowledge. Sir J. Wm. Dawson was President at the meeting in Birmingham in 1886. Born in Nova Scotia in 1820, he devoted himself to the study of the Geology of Canada, and became the leading authority on the subject. He took also an active and influential part in promoting the spread of scientific education in the Dominion, and for a number of years he was Principal and Vice-Chancellor of the M'Gill University, Montreal.

Scientific Method.

Edward Gibbon has told us that diligence and accuracy are the only merits which an historical writer can ascribe to himself. Without doubt they are fundamental qualities necessary for historical research, but in order to bear fruit they require to be exercised by one whose mental qualities are such as to enable him to analyse the data brought together by his diligence, to discriminate between the false and the true, to possess an insight into the complex motives that determine human action, to be able to recognise those facts and incidents which had exercised either a primary or only a secondary influence on the affairs of nations, or on the thoughts and doings of the person whose character he is depicting.

In scientific research, also, diligence and accuracy are fundamental qualities. By their application new facts are discovered and tabulated, their order of succession is ascertained, and a wider and more intimate knowledge of the processes of nature is acquired. But to decide on their true significance a well-balanced mind and the exercise of prolonged thought and reflection are needed. William Harvey, the father of exact research in physiology, in his memorable work 'De Motu Cordis et Sanguinis,' published more than two centuries ago, tells us of the great and daily diligence which he exercised in the course of his investigations, and the numerous observations and experiments which he collated. At the same time he refers repeatedly to his cogitations and reflections on the meaning of what he had observed, without which the complicated movements of the heart could not have been analysed, their significance determined, and the circulation of the blood in a continuous stream definitely established. Early in the present century, Carl Ernst von Baer, the father of embryological research, showed the importance which he attached to the combination of observation with meditation by placing side by side on the title-page of his famous treatise 'Ueber Entwickelungsgeschichte der Thiere' (1828) the words *Beobachtung und Reflexion.*

Though I have drawn from biological science my illustrations of the need of this combination, it must not be inferred that it applies exclu-

sively to one branch of scientific inquiry ; the conjunction influences and determines progress in all the sciences, and when associated with a sufficient touch of imagination, when the power of seeing is conjoined with the faculty of foreseeing, of projecting the mind into the future, we may expect something more than the discovery of isolated facts ; their co-ordination and the enunciation of new principles and laws will necessarily follow.

Scientific method consists, therefore, in close observation, frequently repeated so as to eliminate the possibility of erroneous seeing ; in experiments checked and controlled in every direction in which fallacies might arise ; in continuous reflection on the appearances and phenomena observed, and in logically reasoning out their meaning and the conclusions to be drawn from them. Were the method followed out in its integrity by all who are engaged in scientific investigations, the time and labour expended in correcting errors committed by ourselves or by other observers and experimentalists would be saved, and the volumes devoted annually to scientific literature would be materially diminished in size. Were it applied, as far as the conditions of life admit, to the conduct and management of human affairs, we should not require to be told, when critical periods in our welfare as a nation arise, that we shall muddle through somehow. Recent experience has taught us that wise discretion and careful prevision are as necessary in the direction of public affairs as in the pursuit of science, and in both instances, when properly exercised, they enable us to reach with comparative certainty the goal which we strive to attain.

Improvements in Means of Observation.

Whilst certain principles of research are common to all the sciences, each great division requires for its investigation specialised arrangements to insure its progress. Nothing contributes so much to the advancement of knowledge as improvements in the means of observation, either by the discovery of new adjuncts to research, or by a fresh adaptation of old methods. In the industrial arts, the introduction of a new kind of raw material, the recognition that a mixture or blending is often more serviceable than when the substances employed are uncombined, the discovery of new processes of treating the articles used in manufactures, the invention of improved machinery, all lead to the expansion of trade, to the occupation of the people, and to the development of great industrial centres. In science, also, the invention and employment of new and more precise instruments and appliances enable us to appreciate more clearly the signification of facts and phenomena which were previously obscure, and to penetrate more deeply into the mysteries of nature. They mark fresh departures in the history of science, and provide a firm base of support from which a continuous advance may be made and fresh conceptions of nature can be evolved

It is not my intention, even if I possessed the requisite knowledge, to undertake so arduous a task as to review the progress which has recently been made in the great body of sciences which lie within the domain of the British Association. As my occupation in life has required me to give attention to the science which deals with the structure and organisation of the bodies of man and animals—a science which either includes within its scope or has intimate and widespread relations to comparative anatomy, embryology, morphology, zoology, physiology, and anthropology—I shall limit myself to the attempt to bring before you some of the more important observations and conclusions which have a bearing on the present position of the subject. As this is the closing year of the century, it will not, I think, be out of place to refer to the changes which a hundred years have brought about in our fundamental conceptions of the structure of animals. In science, as in business, it is well from time to time to take stock of what we have been doing, so that we may realise where we stand and ascertain the balance to our credit in the scientific ledger.

So far back as the time of the ancient Greeks it was known that the human body and those of the more highly organised animals were not homogeneous, but were built up of parts, the *partes dissimilares* (τὰ ἀνόμοια μέρη) of Aristotle, which differed from each other in form, colour, texture, consistency, and properties. These parts were familiarly known as the bones, muscles, sinews, blood-vessels, glands, brain, nerves, and so on. As the centuries rolled on, and as observers and observations multiplied, a more and more precise knowledge of these parts throughout the Animal Kingdom was obtained, and various attempts were made to classify animals in accordance with their forms and structure. During the concluding years of the last century and the earlier part of the present, the Hunters, William and John, in our country, the Meckels in Germany, Cuvier and Saint-Hilaire in France, gave an enormous impetus to anatomical studies, and contributed largely to our knowledge of the construction of the bodies of animals. But whilst by these and other observers the most salient and, if I may use the expression, the grosser characters of animal organisation had been recognised, little was known of the more intimate structure or texture of the parts. So far as could be determined by the unassisted vision, and so much as could be recognised by the use of a simple lens, had indeed been ascertained, and it was known that muscles, nerves, and tendons were composed of threads or fibres, that the blood- and lymph-vessels were tubes, that the parts which we call fasciæ and aponeuroses were thin membranes, and so on.

Early in the present century Xavier Bichat, one of the most brilliant men of science during the Napoleonic era in France, published his 'Anatomie Générale,' in which he formulated important general principles. Every animal is an assemblage of different organs, each of which discharges a function, and acting together, each in its own way, assists in the

preservation of the whole. The organs are, as it were, special machines situated in the general building which constitutes the factory or body of the individual. But, further, each organ or special machine is itself formed of tissues which possess different properties. Some, as the blood-vessels, nerves, fibrous tissues, &c., are generally distributed throughout the animal body, whilst others, as bones, muscles, cartilage, &c., are found only in certain definite localities. Whilst Bichat had acquired a definite philosophical conception of the general principles of construction and of the distribution of the tissues, neither he nor his pupil Béclard was in a position to determine the essential nature of the structural elements. The means and appliances at their disposal and at that of other observers in their generation were not sufficiently potent to complete the analysis.

Attempts were made in the third decennium of this century to improve the methods of examining minute objects by the manufacture of compound lenses, and, by doing away with chromatic and spherical aberration, to obtain, in addition to magnification of the object, a relatively large flat field of vision with clearness and sharpness of definition. When in January 1830 Joseph Jackson Lister read to the Royal Society his memoir 'On some properties in achromatic object-glasses applicable to the improvement of microscopes,' he announced the principles on which combinations of lenses could be arranged, which would possess these qualities. By the skill of our opticians, microscopes have now for more than half a century been constructed which, in the hands of competent observers, have influenced and extended biological science with results comparable to those obtained by the astronomer through improvements in the telescope.

In the study of the minute structure of plants and animals the observer has frequently to deal with tissues and organs, most of which possess such softness and delicacy of substance and outline that, even when microscopes of the best construction are employed, the determination of the intimate nature of the tissue, and the precise relation which one element of an organ bears to the other constituent elements, is in many instances a matter of difficulty. Hence additional methods have had to be devised in order to facilitate study and to give precision and accuracy to our observations. It is difficult for one of the younger generation of biologists, with all the appliances of a well-equipped laboratory at his command, with experienced teachers to direct him in his work, and with excellent text-books, in which the modern methods are described, to realise the conditions under which his predecessors worked half a century ago. Laboratories for minute biological research had not been constructed, the practical teaching of histology and embryology had not been organised, experience in methods of work had not accumulated; each man was left to his individual efforts, and had to puzzle his way through the complications of structure to the best of his power. Staining and hardening

reagents were unknown. The double-bladed knife invented by Valentin, held in the hand, was the only improvement on the scalpel or razor for cutting thin, more or less translucent slices suitable for microscopic examination; mechanical section-cutters and freezing arrangements had not been devised. The tools at the disposal of the microscopist were little more than knife, forceps, scissors, needles; with acetic acid, glycerine, and Canada balsam as reagents. But in the employment of the newer methods of research care has to be taken, more especially when hardening and staining reagents are used, to discriminate between appearances which are to be interpreted as indicating natural characters, and those which are only artificial productions.

Notwithstanding the difficulties attendant on the study of the more delicate tissues, the compound achromatic microscope provided anatomists with an instrument of great penetrative power. Between the years 1830 and 1850 a number of acute observers applied themselves with much energy and enthusiasm to the examination of the minute structure of the tissues and organs in plants and animals.

Cell Theory.

It had, indeed, long been recognised that the tissues of plants were to a large extent composed of minute vesicular bodies, technically called cells (Hooke, Malpighi, Grew). In 1831 the discovery was made by the great botanist, Robert Brown, that in many families of plants a circular spot, which he named areola or nucleus, was present in each cell; and in 1838 M. J. Schleiden published the fact that a similar spot or nucleus was a universal elementary organ in vegetables. In the tissues of animals also structures had begun to be recognised comparable with the cells and nuclei of the vegetable tissues, and in 1839 Theodore Schwann announced the important generalisation that there is one universal principle of development for the elementary part of organisms, however different they may be in appearance, and that this principle is the formation of cells. The enunciation of the fundamental principle that the elementary tissues consisted of cells constituted a step in the progress of biological science, which will for ever stamp the century now drawing to a close with a character and renown equalling those which it has derived from the most brilliant discoveries in the physical sciences. It provided biologists with the visible anatomical units through which the external forces operating on, and the energy generated in, living matter come into play. It dispelled for ever the old mystical idea of the influence exercised by vapours or spirits in living organisms. It supplied the physiologist and pathologist with the specific structures through the agency of which the functions of organisms are discharged in health and disease. It exerted an enormous influence on the progress of practical medicine. A review of the progress of knowledge of the cell may appropriately enter into an address on this occasion.

Structure of Cells.

A cell is a living particle, so minute that it needs a microscope for its examination; it grows in size, maintains itself in a state of activity, responds to the action of stimuli, reproduces its kind, and in the course of time it degenerates and dies.

Let us glance at the structure of a cell to determine its constituent parts and the *rôle* which each plays in the function to be discharged. The original conception of a cell, based upon the study of the vegetable tissues, was a minute vesicle enclosed by a definite wall, which exercised chemical or metabolic changes on the surrounding material and secreted into the vesicle its characteristic contents. A similar conception was at first also entertained regarding the cells of animal tissues; but as observations multiplied, it was seen that numerous elementary particles, which were obviously in their nature cells, did not possess an enclosing envelope. A wall ceased to have a primary value as a constituent part of a cell, the necessary vesicular character of which therefore could no longer be entertained.

The other constituent parts of a cell are the cell plasm, which forms the body of the cell, and the nucleus embedded in its substance. Notwithstanding the very minute size of the nucleus, which even in the largest cells is not more than $\frac{1}{500}$th inch in diameter, and usually is considerably smaller, its almost constant form, its well-defined sharp outline, and its power of resisting the action of strong reagents when applied to the cell, have from the period of its discovery by Robert Brown caused histologists to bestow on it much attention. Its structure and chemical composition; its mode of origin; the part which it plays in the formation of new cells, and its function in nutrition and secretion have been investigated.

When examined under favourable conditions in its passive or resting state, the nucleus is seen to be bounded by a membrane which separates it from the cell plasm and gives it the characteristic sharp contour. It contains an apparently structureless nuclear substance, nucleoplasm or enchylema, in which are embedded one or more extremely minute particles called nucleoli, along with a network of exceedingly fine threads or fibres, which in the active living cell play an essential part in the production of new nuclei within the cell. In its chemical composition the nuclear substance consists of albuminous plastin and globulin; and of a special material named nuclein, rich in phosphorus and with an acid reaction. The delicate network within the nucleus consists apparently of the nuclein, a substance which stains with carmine and other dyes, a property which enables the changes, which take place in the network in the production of young cells, to be more readily seen and followed out by the observer.

The mode of origin of the nucleus and the part which it plays in the production of new cells have been the subject of much discussion.

Schleiden, whose observations, published in 1838, were made on the cells of plants, believed that within the cell a nucleolus first appeared, and that around it molecules aggregated to form the nucleus. Schwann again, whose observations were mostly made on the cells of animals, considered that an amorphous material existed in organised bodies, which he called cytoblastema. It formed the contents of cells, or it might be situated free or external to them. He figuratively compared it to a mother liquor in which crystals are formed. Either in the cytoblastema within the cells or in that situated external to them, the aggregation of molecules around a nucleolus to form a nucleus might occur, and, when once the nucleus had been formed, in its turn it would serve as a centre of aggregation of additional molecules from which a new cell would be produced. He regarded therefore the formation of nuclei and cells as possible in two ways: one within pre-existing cells (endogenous cell-formation), the other in a free blastema lying external to cells (free cell-formation). In animals, he says, the endogenous method is rare, and the customary origin is in an external blastema. Both Schleiden and Schwann considered that after the cell was formed the nucleus had no permanent influence on the life of the cell, and usually disappeared.

Under the teaching principally of Henle, the famous Professor of Anatomy in Göttingen, the conception of the free formation of nuclei and cells in a more or less fluid blastema, by an aggregation of elementary granules and molecules, obtained so much credence, especially amongst those who were engaged in the study of pathological processes, that the origin of cells within pre-existing cells was to a large extent lost sight of. That a parent cell was requisite for the production of new cells seemed to many investigators to be no longer needed. Without doubt this conception of free cell-formation contributed in no small degree to the belief, entertained by various observers, that the simplest plants and animals might arise, without pre-existing parents, in organic fluids destitute of life, by a process of spontaneous generation; a belief which prevailed in many minds almost to the present day. If, as has been stated, the doctrine of abiogenesis cannot be experimentally refuted, on the other hand it has not been experimentally proved. The burden of proof lies with those who hold the doctrine, and the evidence that we possess is all the other way.

Multiplication of Cells.

Although von Mohl, the botanist, seems to have been the first to recognise (1835) in plants a multiplication of cells by division, it was not until attention was given to the study of the egg in various animals, and to the changes which take place in it, attendant on fertilisation, that in the course of time a much more correct conception of the origin of the nucleus and of the part which it plays in the formation of new cells was obtained. Before Schwann had published his classical memoir in 1839,

von Baer and other observers had recognised within the animal ovum the germinal vesicle, which obviously bore to the ovum the relation of a nucleus to a cell. As the methods of observation improved, it was recognised that, within the developing egg, two vesicles appeared where one only had previously existed, to be followed by four vesicles, then eight, and so on in multiple progression until the ovum contained a multitude of vesicles, each of which possessed a nucleus. The vesicles were obviously cells which had arisen within the original germ-cell or ovum. These changes were systematically described by Martin Barry so long ago as 1839 and 1840 in two memoirs communicated to the Royal Society of London, and the appearance produced, on account of the irregularities of the surface occasioned by the production of new vesicles, was named by him the mulberry-like structure. He further pointed out that the vesicles arranged themselves as a layer within the envelope of the egg or zona pellucida, and that the whole embryo was composed of cells filled with the foundations of other cells. He recognised that the new cells were derived from the germinal vesicle or nucleus of the ovum, the contents of which entered into the formation of the first two cells, each of which had its nucleus, which in its turn resolved itself into other cells, and by a repetition of the process into a greater number. The endogenous origin of new cells within a pre-existing cell and the process which we now term the segmentation of the yolk were successfully demonstrated. In a third memoir, published in 1841, Barry definitely stated that young cells originated through division of the nucleus of the parent cell, instead of arising, as a product of crystallisation, in the fluid cytoblastema of the parent cell or in a blastema situated external to the cell.

In a memoir published in 1842, John Goodsir advocated the view that the nucleus is the reproductive organ of the cell, and that from it, as from a germinal spot, new cells were formed. In a paper, published three years later, on nutritive centres, he described cells, the nuclei of which were the permanent source of successive broods of young cells, which from time to time occupied the cavity of the parent cell. He extended also his observations on the endogenous formation of cells to the cartilage cells in the process of inflammation and to other tissues undergoing pathological changes. Corroborative observations on endogenous formation were also given by his brother Harry Goodsir in 1845. These observations on the part which the nucleus plays by cleavage in the formation of young cells by endogenous development from a parent centre—that an organic continuity existed between a mother cell and its descendants through the nucleus—constituted a great step in advance of the views entertained by Schleiden and Schwann, and showed that Barry and the Goodsirs had a deeper insight into the nature and functions of cells than was possessed by most of their contemporaries, and are of the highest importance when viewed in the light of recent observations.

In 1841 Robert Remak published an account of the presence of two

nuclei in the blood corpuscles of the chick and the pig, which he regarded as evidence of the production of new corpuscles by division of the nucleus within a parent cell; but it was not until some years afterwards (1850 to 1855) that he recorded additional observations and recognised that division of the nucleus was the starting-point for the multiplication of cells in the ovum and in the tissues generally. Remak's view was that the process of cell division began with the cleavage of the nucleolus, followed by that of the nucleus, and that again by cleavage of the body of the cell and of its membrane. Kölliker had previously, in 1843, described the multiplication of nuclei in the ova of parasitic worms, and drew the inference that in the formation of young cells within the egg the nucleus underwent cleavage, and that each of its divisions entered into the formation of a new cell. By these observations, and by others subsequently made, it became obvious that the multiplication of animal cells, either by division of the nucleus within the cell, or by the budding off of a part of the protoplasm of the cell, was to be regarded as a widely spread and probably a universal process, and that each new cell arose from a parent cell.

Pathological observers were, however, for the most part inclined to consider free cell-formation in a blastema or exudation by an aggregation of molecules, in accordance with the views of Henle, as a common phenomenon. This proposition was attacked with great energy by Virchow in a series of memoirs published in his 'Archiv,' commencing in Vol. 1, 1847, and finally received its death-blow in his published lectures on Cellular Pathology, 1858. He maintained that in pathological structures there was no instance of cell development *de novo*; where a cell existed, there one must have been before. Cell-formation was a continuous development by descent, which he formulated in the expression *omnis cellula e cellulâ.*

Karyokinesis.

Whilst the descent of cells from pre-existing cells by division of the nucleus during the development of the egg, in the embryos of plants and animals, and in adult vegetable and animal tissues, both in healthy and diseased conditions, had now become generally recognised, the mechanism of the process by which the cleavage of the nucleus took place was for a long time unknown. The discovery had to be deferred until the optician had been able to construct lenses of a higher penetrative power, and the microscopist had learned the use of colouring agents capable of dyeing the finest elements of the tissues. There was reason to believe that in some cases a direct cleavage of the nucleus, to be followed by a corresponding division of the cell into two parts, did occur. In the period between 1870 and 1880 observations were made by Schneider, Strasburger, Bütschli, Fol, van Beneden, and Flemming, which showed that the division of the nucleus and the cell was due to a series of very remarkable changes, now known as indirect nuclear and cell division, or karyo-

kinesis. The changes within the nucleus are of so complex a character that it is impossible to follow them in detail without the use of appropriate illustrations. I shall have to content myself, therefore, with an elementary sketch of the process.

I have previously stated that the nucleus in its passive or resting stage contains a very delicate network of threads or fibres. The first stage in the process of nuclear division consists in the threads arranging themselves in loops and forming a compact coil within the nucleus. The coil then becomes looser, the loops of threads shorten and thicken, and somewhat later each looped thread splits longitudinally into two portions. As the threads stain when colouring agents are applied to them, they are called chromatin fibres, and the loose coil is the chromosome (Waldeyer).

As the process continues, the investing membrane of the nucleus disappears, and the loops of threads arrange themselves within the nucleus so that the closed ends of the loops are directed to a common centre, from which the loops radiate outwards and produce a starlike figure (aster). At the same time clusters of extremely delicate lines appear both in the nucleoplasm and in the body of the cell, named the achromatic figure, which has a spindle-like form with two opposite poles, and stains much more feebly than the chromatic fibres. The loops of the chromatic star then arrange themselves in the equatorial plane of the spindle, and bending round turn their closed ends towards the periphery of the nucleus and the cell.

The next stage marks an important step in the process of division of the nucleus. The two longitudinal portions, into which each looped thread had previously split, now separate from each other, and whilst one part migrates to one pole of the spindle, the other moves to the opposite pole, and the free ends of each loop are directed towards its equator (metakinesis). By this division of the chromatin fibres, and their separation from each other to opposite poles of the spindle, two star-like chromatin figures are produced (dyaster).

Each group of fibres thickens, shortens, becomes surrounded by a membrane, and forms a new or daughter nucleus (dispirem). Two nuclei therefore have arisen within the cell by the division of that which had previously existed, and the expression formulated by Flemming—*omnis nucleus e nucleo*—is justified. Whilst this stage is in course of being completed, the body of the cell becomes constricted in the equatorial plane of the spindle, and, as the constriction deepens, it separates into two parts, each containing a daughter nucleus, so that two nucleated cells have arisen out of a pre-existing cell.

A repetition of the process in each of these cells leads to the formation of other cells, and, although modifications in details are found in different species of plants and animals, the multiplication of cells in the egg and in the tissues generally on similar lines is now a thoroughly established fact in biological science.

In the study of karyokinesis, importance has been attached to the number of chromosomes in the nucleus of the cell. Flemming had seen in the Salamander twenty-four chromosome fibres, which seems to be a constant number in the cells of epithelium and connective tissues. In other cells again, especially in the ova of certain animals, the number is smaller, and fourteen, twelve, four, and even two only have been described. The theory formulated by Boveri that the number of chromosomes is constant for each species, and that in the karyokinetic figures corresponding numbers are found in homologous cells, seems to be not improbable.

In the preceding description I have incidentally referred to the appearance in the proliferating cell of an achromatic spindle-like figure. Although this was recognised by Fol in 1873, it is only during the last ten or twelve years that attention has been paid to its more minute arrangements and possible signification in cell-division.

The pole at each end of the spindle lies in the cell plasm which surrounds the nucleus. In the centre of each pole is a somewhat opaque spot (central body) surrounded by a clear space, which, along with the spot, constitutes the centrosome or the sphere of attraction. From each centrosome extremely delicate lines may be seen to radiate in two directions. One set extends towards the pole at the opposite end of the spindle and, meeting or coming into close proximity with radiations from it, constitutes the body of the spindle, which, like a perforated mantle, forms an imperfect envelope around the nucleus during the process of division. The other set of radiations is called the polar, and extends in the region of the pole towards the periphery of the cell.

The question has been much discussed whether any constituent part of the achromatic figure, or the entire figure, exists in the cell as a permanent structure in its resting phase; or if it is only present during the process of karyokinesis. During the development of the egg the formation of young cells, by division of the segmentation nucleus, is so rapid and continuous that the achromatic figure, with the centrosome in the pole of the spindle, is a readily recognisable object in each cell. The polar and spindle-like radiations are in evidence during karyokinesis, and have apparently a temporary endurance and function. On the other hand, van Beneden and Boveri were of opinion that the central body of the centrosome did not disappear when the division of the nucleus came to an end, but that it remained as a constituent part of a cell lying in the cell plasm near to the nucleus. Flemming has seen the central body with its sphere in leucocytes, as well as in epithelial cells and those of other tissues. Subsequently Heidenhain and other histologists have recorded similar observations. It would seem, therefore, as if there were reason to regard the centrosome, like the nucleus, as a permanent constituent of a cell. This view, however, is not universally entertained. If not always capable of demonstration in the resting stage of a cell, it is doubtless to be regarded as potentially present, and ready to assume,

along with the radiations, a characteristic appearance when the process of nuclear division is about to begin.

One can scarcely regard the presence of so remarkable an appearance as the achromatic figure without associating with it an important function in the economy of the cell. As from the centrosome at the pole of the spindle both sets of radiations diverge, it is not unlikely that it acts as a centre or sphere of energy and attraction. By some observers the radiations are regarded as substantive fibrillar structures, elastic or even contractile in their properties. Others, again, look upon them as morphological expressions of chemical and dynamical energy in the protoplasm of the cell body. On either theory we may assume that they indicate an influence, emanating, it may be, from the centrosome, and capable of being exercised both on the cell plasm and on the nucleus contained in it. On the contractile theory, the radiations which form the body of the spindle, either by actual traction of the supposed fibrillæ or by their pressure on the nucleus which they surround, might impel during karyokinesis the dividing chromosome elements towards the poles of the spindle, to form there the daughter nuclei. On the dynamical theory, the chemical and physical energy in the centrosome might influence the cell plasm and the nucleus, and attract the chromosome elements of the nucleus to the poles of the spindle. The radiated appearance would therefore be consequent and attendant on the physico-chemical activity of the centrosome. One or other of these theories may also be applied to the interpretation of the significance of the polar radiations.

Cell Plasm.

In the cells of plants, in addition to the cell wall, the cell body and the cell juice require to be examined. The material of the cell body, or the cell contents, was named by von Mohl (1846) protoplasm, and consisted of a colourless tenacious substance which partly lined the cell wall (primordial utricle), and partly traversed the interior of the cell as delicate threads enclosing spaces (vacuoles) in which the cell juice was contained. In the protoplasm the nucleus was embedded. Nägeli, about the same time, had also recognised the difference between the protoplasm and the other contents of vegetable cells, and had noticed its nitrogenous composition.

Though the analogy with a closed bladder or vesicle could no longer be sustained in the animal tissues, the name 'cell' continued to be retained for descriptive purposes, and the body of the cell was spoken of as a more or less soft substance enclosing a nucleus (Leydig). In 1861 Max Schultze adopted for the substance forming the body of the animal cell the term 'protoplasm.' He defined a cell to be a particle of protoplasm in the substance of which a nucleus was situated. He regarded the protoplasm, as indeed had previously been pointed out by the botanist Unger, as essentially the same as the contractile sarcode which

constitutes the body and pseudopodia of the Amœba and other Rhizopoda. As the term 'protoplasm,' as well as that of 'bioplasm' employed by Lionel Beale in a somewhat similar though not precisely identical sense, involves certain theoretical views of the origin and function of the body of the cell, it would be better to apply to it the more purely descriptive term 'cytoplasm' or 'cell plasm.'

Schultze defined protoplasm as a homogeneous, glassy, tenacious material, of a jelly-like or somewhat firmer consistency, in which numerous minute granules were embedded. He regarded it as the part of the cell especially endowed with vital energy, whilst the exact function of the nucleus could not be defined. Based upon this conception of the jelly-like character of protoplasm, the idea for a time prevailed that a structureless, dimly granular, jelly or slime destitute of organisation, possessed great physiological activity, and was the medium through which the phenomena of life were displayed.

More accurate conceptions of the nature of the cell plasm soon began to be entertained. Brücke recognised that the body of the cell was not simple, but had a complex organisation. Flemming observed that the cell plasm contained extremely delicate threads, which frequently formed a network, the interspaces of which were occupied by a more homogeneous substance. Where the threads crossed each other, granular particles (mikrosomen) were situated. Bütschli considered that he could recognise in the cell plasm a honeycomb-like appearance, as if it consisted of excessively minute chambers in which a homogeneous more or less fluid material was contained. The polar and spindle-like radiations visible during the process of karyokinesis, which have already been referred to, and the presence of the centrosome, possibly even during the resting stage of the cell, furnished additional illustrations of differentiation within the cell plasm. In many cells there appears also to be a difference in the character of the cell plasm which immediately surrounds the nucleus and that which lies at and near the periphery of the cell. The peripheral part (ektoplasma) is more compact and gives a definite outline to the cell, although not necessarily differentiating into a cell membrane. The inner part (endoplasma) is softer, and is distinguished by a more distinct granular appearance, and by containing the products specially formed in each particular kind of cell during the nutritive process.

By the researches of numerous investigators on the internal organisation of cells in plants and animals, a large body of evidence has now been accumulated, which shows that both the nucleus and the cell plasm consist of something more than a homogeneous, more or less viscid, slimy material. Recognisable objects in the form of granules, threads, or fibres can be distinguished in each. The cell plasm and the nucleus respectively are therefore not of the same constitution throughout, but possess polymorphic characters, the study of which in health and the changes produced by disease will for many years to come form important matters for investigation.

Function of Cells.

It has already been stated that, when new cells arise within pre-existing cells, division of the nucleus is associated with cleavage of the cell plasm, so that it participates in the process of new cell-formation. Undoubtedly, however, its *rôle* is not limited to this function. It also plays an important part in secretion, nutrition, and the special functions discharged by the cells in the tissues and organs of which they form morphological elements.

Between 1838 and 1842 observations were made which showed that cells were constituent parts of secreting glands and mucous membranes (Schwann, Henle). In 1842 John Goodsir communicated to the Royal Society of Edinburgh a memoir on secreting structures, in which he established the principle that cells are the ultimate secreting agents; he recognised in the cells of the liver, kidney, and other organs the characteristic secretion of each gland. The secretion was, he said, situated between the nucleus and the cell wall. At first he thought that, as the nucleus was the reproductive organ of the cell, the secretion was formed in the interior of the cell by the agency of the cell wall; but three years later he regarded it as a product of the nucleus. The study of the process of spermatogenesis by his brother, Harry Goodsir, in which the head of the spermatozoon was found to correspond with the nucleus of the cell in which the spermatozoon arose, gave support to the view that the nucleus played an important part in the genesis of the characteristic product of the gland cell.

The physiological activity of the cell plasm and its complex chemical constitution soon after began to be recognised. Some years before Max Schultze had published his memoirs on the characters of protoplasm, Brücke had shown that the well-known changes in tint in the skin of the Chamæleon were due to pigment granules situated in cells in the skin which were sometimes diffused throughout the cells, at others concentrated in the centre. Similar observations on the skin of the frog were made in 1854 by von Wittich and Harless. The movements were regarded as due to contraction of the cell wall on its contents. In a most interesting paper on the pigmentary system in the frog, published in 1858, Lord Lister demonstrated that the pigment granules moved in the cell plasma, by forces resident within the cell itself, acting under the influence of an external stimulant, and not by a contractility of the wall. Under some conditions the pigment was attracted to the centre of the cell, when the skin became pale; under other conditions the pigment was diffused throughout the body and the branches of the cell, and gave to the skin a dark colour. It was also experimentally shown that a potent influence over these movements was exercised by the nervous system.

The study of the cells of glands engaged in secretion, even when the

secretion is colourless, and the comparison of their appearance when secretion is going on with that seen when the cells are at rest, have shown that the cell plasm is much more granular and opaque, and contains larger particles, during activity than when the cell is passive; the body of the cell swells out from an increase in the contents of its plasm, and chemical changes accompany the act of secretion. Ample evidence, therefore, is at hand to support the position taken by John Goodsir, nearly sixty years ago, that secretions are formed within cells, and lie in that part of the cell which we now say consists of the cell plasm; that each secreting cell is endowed with its own peculiar property, according to the organ in which it is situated, so that bile is formed by the cells in the liver, milk by those in the mamma, and so on.

Intimately associated with the process of secretion is that of nutrition. As the cell plasm lies at the periphery of a cell, and as it is, alike in secretion and nutrition, brought into closest relation with the surrounding medium, from which the pabulum is derived, it is necessarily associated with nutritive activity. Its position enables it to absorb nutritive material directly from without, and in the process of growth it increases in amount by interstitial changes and additions throughout its substance, and not by mere accretions on its surface.

Hitherto I have spoken of a cell as a unit, independent of its neighbours as regards its nutrition and the other functions which it has to discharge. The question has, however, been discussed, whether in a tissue composed of cells closely packed together cell plasm may not give origin to processes or threads which are in contact or continuous with corresponding processes of adjoining cells, and that cells may therefore, to some extent, lose their individuality in the colony of which they are members. Appearances were recognised between 1863 and 1870 by Schrön and others in the deeper cells of the epidermis and of some mucous membranes which gave sanction to this view, and it seems possible, through contact or continuity of threads connecting a cell with its neighbours, that cells may exercise a direct influence on each other.

Nägeli, the botanist, as the foundation of a mechanico-physiological theory of descent, considered that in plants a network of cell plasm, named by him idio-plasm, extended throughout the whole of the plant, forming its specific molecular constitution, and that growth and activity were regulated by its conditions of tension and movements (1884).

The study of the structure of plants with special reference to the presence of an intercellular network has for some years been pursued by Walter Gardiner (1882–97), who has demonstrated threads of cell plasm protruding through the walls of vegetable cells and continuous with similar threads from adjoining cells. Structurally, therefore, a plant may be conceived to be built up of a nucleated cytoplasmic network, each nucleus with the branching cell plasm surrounding it being a centre of activity. On this view a cell would retain to some extent its individuality,

though, as Gardiner contends, the connecting threads would be the medium for the conduction of impulses and of food from a cell to those which lie around it. For the plant cell therefore, as has long been accepted in the animal cell, the wall is reduced to a secondary position, and the active constituent is the nucleated cell plasm. It is not unlikely that the absence of a controlling nervous system in plants requires the plasm of adjoining cells to be brought into more immediate contact and continuity than is the case with the generality of animal cells, so as to provide a mechanism for harmonising the nutritive and other functional processes in the different areas in the body of the plant. In this particular, it is of interest to note that the epithelial tissues in animals, where somewhat similar connecting arrangements occur, are only indirectly associated with the nervous and vascular systems, so that, as in plants, the cells may require, for nutritive and other purposes, to act and react directly on each other.

Nerve Cells.

Of recent years great attention has been paid to the intimate structure of nerve cells, and to the appearance which they present when in the exercise of their functional activity. A nerve cell is not a secreting cell; that is, it does not derive from the blood or surrounding fluid a pabulum which it elaborates into a visible, palpable secretion characteristic of the organ of which the cell is a constituent element, to be in due course discharged into a duct which conveys the secretion out of the gland. Nerve cells, through the metabolic changes which take place in them in connection with their nutrition, are associated with the production of the form of energy termed nerve energy, specially exhibited by animals which possess a nervous system. It has long been known that every nerve cell has a body in which a relatively large nucleus is situated. A most important discovery was the recognition that the body of every nerve cell had one or more processes growing out from it. More recently it has been proved, chiefly through the researches of Schultze, His, Golgi, and Ramon y Cajal, that at least one of the processes, the axon of the nerve cell, is continued into the axial cylinder of a nerve fibre, and that in the multipolar nerve cell the other processes, or dendrites, branch and ramify for some distance away from the body. A nerve fibre is therefore an essential part of the cell with which it is continuous, and the cell, its processes, the nerve fibre and the collaterals which arise from the nerve fibre collectively form a neuron or structural nerve unit (Waldeyer). The nucleated body of the nerve cell is the physiological centre of the unit.

The cell plasm occupies both the body of the nerve cell and its processes. The intimate structure of the plasm has, by improved methods of observation introduced during the last eight years by Nissl, and conducted on similar lines by other investigators, become more definitely understood. It has been ascertained that it possesses two distinct

characters which imply different structures. One stains deeply on the addition of certain dyes, and is named chromophile or chromatic substance; the other, which does not possess a similar property, is the achromatic network. The chromophile is found in the cell body and the dendritic processes, but not in the axon. It occurs in the form of granular particles, which may be scattered throughout the plasm, or aggregated into little heaps which are elongated or fusiform in shape and appear as distinct coloured particles or masses. The achromatic network is found in the cell body and the dendrites, and is continued also into the axon, where it forms the axial cylinder of the nerve fibre. It consists apparently of delicate threads or fibrillæ, in the meshes of which a homogeneous material, such as is found in cell plasm generally, is contained. In the nerve cells, as in other cells, the plasm is without doubt concerned in the process of cell nutrition. The achromatic fibrillæ exercise an important influence on the axon or nerve fibre with which they are continuous, and probably they conduct the nerve impulses which manifest themselves in the form of nerve energy. The dendritic processes of a multipolar nerve cell ramify in close relation with similar processes branching from other cells in the same group. The collaterals and the free end of the axon fibre process branch and ramify in association with the body of a nerve cell or of its dendrites. We cannot say that these parts are directly continuous with each other to form an intercellular network, but they are apparently in apposition, and through contact exercise influence one on the other in the transmission of nerve impulses.

There is evidence to show that in the nerve cell the nucleus, as well as the cell plasm, is an effective agent in nutrition. When the cell is functionally active, both the cell body and the nucleus increase in size (Vas, G. Mann, Lugaro); on the other hand, when nerve cells are fatigued through excessive use, the nucleus decreases in size and shrivels; the cell plasm also shrinks, and its coloured or chromophile constituent becomes diminished in quantity, as if it had been consumed during the prolonged use of the cell (Hodge, Mann, Lugaro). It is interesting also to note that in hibernating animals in the winter season, when their functional activity is reduced to a minimum, the chromophile in the plasm of the nerve cells is much smaller in amount than when the animal is leading an active life in the spring and summer (G. Levi).

When a nerve cell has attained its normal size it does not seem to be capable of reproducing new cells in its substance by a process of karyokinesis, such as takes place when young cells arise in the egg and in the tissues generally. It would appear that nerve cells are so highly specialised in their association with the evolution of nerve energy, that they have ceased to have the power of reproducing their kind, and the metabolic changes both in cell plasm and nucleus are needed to enable them to discharge their very peculiar function. Hence it follows that when a portion of the brain or other nerve-centre is destroyed, the

injury is not repaired by the production of fresh specimens of their characteristic cells, as would be the case in injuries to bones and tendons.

In our endeavours to differentiate the function of the nucleus from that of the cell plasm, we should not regard the former as concerned only in the production of young cells, and the latter as the exclusive agent in growth, nutrition, and, where gland cells are concerned, in the formation of their characteristic products. As regards cell reproduction also, though the process of division begins in the nucleus in its chromosome constituents, the achromatic figure in the cell plasm undoubtedly plays a part, and the cell plasm itself ultimately undergoes cleavage.

A few years ago the tendency amongst biologists was to ignore or attach but little importance to the physiological use of the nucleus in the nucleated cell, and to regard the protoplasm as the essential and active constituent of living matter; so much so, indeed, was this the case that independent organisms regarded as distinct species were described as consisting of protoplasm destitute of a nucleus; also that scraps of protoplasm separated from larger nucleated masses could, when isolated, exhibit vital phenomena. There is reason to believe that a fragment of protoplasm, when isolated from the nucleus of a cell, though retaining its contractility and capable of nourishing itself for a short time, cannot increase in amount, act as a secreting structure, or reproduce its kind: it soon loses its activity, withers, and dies. In order that these qualities of living matter should be retained, a nucleus is by most observers regarded as necessary (Nussbaum, Gruber, Haberlandt, Korschelt), and that for the complete manifestation of vital activity both nucleus and cell plasm are required.

Bacteria.

The observations of Cohn, made about thirty years ago, and those of De Bary shortly afterwards, brought into notice a group of organisms to which the name 'bacterium' or 'microbe' is given. They were seen to vary in shape: some were rounded specks called cocci, others were straight rods called bacilli, others were curved or spiral rods, vibrios or spirillæ. All were characterised by their extreme minuteness, and required for their examination the highest powers of the best microscopes. Many bacteria measure in their least diameter not more than $\frac{1}{25000}$th of an inch, $\frac{1}{10}$th the diameter of a human white blood corpuscle. Through the researches of Pasteur, Lord Lister, Koch, and other observers, bacteria have been shown to play an important part in nature. They exercise a very remarkable power over organic substances, especially those which are complex in chemical constitution, and can resolve them into simpler combinations. Owing to this property, some bacteria are of great economic value, and without their agency many of our industries could not be pursued; others again, and these are the most talked of, exercise a malign influence in the production of the most deadly diseases which afflict man and the domestic animals.

Great attention has been given to the structure of bacteria and to their mode of propagation. When examined in the living state and magnified about 2,000 times, a bacterium appears as a homogeneous particle, with a sharp definite outline, though a membranous envelope or wall, distinct from the body of the bacterium, cannot at first be recognised; but when treated with reagents a membranous envelope appears, the presence of which, without doubt, gives precision of form to the bacterium. The substance within the membrane contains granules which can be dyed with colouring agents. Owing to their extreme minuteness it is difficult to pronounce an opinion on the nature of the chromatine granules and the substance in which they lie. Some observers regard this substance as nuclear material, invested by only a thin layer of protoplasm, on which view a bacterium would be a nucleated cell. Others consider the bacterium as formed of protoplasm containing granules capable of being coloured, which are a part of the protoplasm itself, and not a nuclear substance. On the latter view, bacteria would consist of cell plasm enclosed in a membrane and destitute of a nucleus. Whatever be the nature of the granule-containing material, each bacterium is regarded as a cell, the minutest and simplest living particle capable of an independent existence that has yet been discovered.

Bacteria cells, like cells generally, can reproduce their kind. They multiply by simple fission, probably with an ingrowth of the cell wall, but without the karyokinetic phenomena observed in nucleated cells. Each cell gives rise to two daughter cells, which may for a time remain attached to each other and form a cluster or a chain, or they may separate and become independent isolated cells. The multiplication, under favourable conditions of light, air, temperature, moisture, and food, goes on with extraordinary rapidity, so that in a few hours many thousand new individuals may arise from a parent bacterium.

Connected with the life-history of a bacterium cell is the formation in its substance, in many species and under certain conditions, of a highly refractile shiny particle called a spore. At first sight a spore seems as if it were the nucleus of the bacterium cell, but it is not always present when multiplication by cleavage is taking place, and when present it does not appear to take part in the fission. On the other hand, a spore, from the character of its envelope, possesses great power of resistance, so that dried bacteria, when placed in conditions favourable to germination, can through their spores germinate and resume an active existence. Spore formation seems, therefore, to be a provision for continuing the life of the bacterium under conditions which, if spores had not formed, would have been the cause of its death.

The time has gone by to search for the origin of living organisms by a spontaneous aggregation of molecules in vegetable or other infusions, or from a layer of formless primordial slime diffused over the bed of the ocean. Living matter during our epoch has been, and continues to be, derived

from pre-existing living matter, even when it possesses the simplicity of structure of a bacterium, and the morphological unit is the cell.

Development of the Egg.

As the future of the entire organism lies in the fertilised egg cell, we may now briefly review the arrangements, consequent on the process of segmentation, which lead to the formation, let us say in the egg of a bird, of the embryo or young chick.

In the latter part of the last century, C. F. Wolff observed that the beginning of the embryo was associated with the formation of layers, and in 1817 Pander demonstrated that in the hen's egg at first one layer, called mucous, appeared, then a second or serous layer, to be followed by a third, intermediate or vascular layer. In 1828 von Baer amplified our knowledge in his famous treatise, which from its grasp of the subject created a new epoch in the science of embryology. It was not, however, until the discovery by Schwann of cells as constant factors in the structure of animals and in their relation to development that the true nature of these layers was determined. We now know that each layer consists of cells, and that all the tissues and organs of the body are derived from them. Numerous observers have devoted themselves for many years to the study of each layer, with the view of determining the share which it takes in the formation of the constituent parts of the body, more especially in the higher animals, and the important conclusion has been arrived at that each kind of tissue invariably arises from one of these layers and from no other.

The layer of cells which contributes, both as regards the number and variety of the tissues derived from it, most largely to the formation of the body is the middle layer or mesoblast. From it the skeleton, the muscles, and other locomotor organs, the true skin, the vascular system, including the blood, and other structures which I need not detail, take their rise. From the inner layer of cells or hypoblast, the principal derivatives are the epithelial lining of the alimentary canal and of the glands which open into it, and the epithelial lining of the air-passages. The outer or epiblast layer of cells gives origin both to the epidermis or scarf skin and to the nervous system. It is interesting to note that from the same layer of the embryo arise parts so different in importance as the cuticle—a mere protecting structure, which is constantly being shed when the skin is subjected to the friction of a towel or the clothes—and the nervous system, including the brain, the most highly differentiated system in the animal body. How completely the cells from which they are derived had diverged from each other in the course of their differentiation in structure and properties is shown by the fact that the cells of the epidermis are continually engaged in reproducing new cells to replace those which are shed, whilst the cells of the nervous system have apparently lost the power of reproducing their kind.

In the early stage of the development of the egg, the cells in a given layer resemble each other in form, and, as far as can be judged from their appearance, are alike in structure and properties. As the development proceeds, the cells begin to show differences in character, and in the course of time the tissues which arise in each layer differentiate from each other and can be readily recognised by the observer. To use the language of von Baer, a generalised structure has become specialised, and each of the special tissues produced exhibits its own structure and properties. These changes are coincident with a rapid multiplication of the cells by cleavage, and thus increase in size of the embryo accompanies specialisation of structure. As the process continues, the embryo gradually assumes the shape characteristic of the species to which its parents belonged, until at length it is fit to be born and to assume a separate existence.

The conversion of cells, at first uniform in character, into tissues of a diverse kind is due to forces inherent in the cells in each layer. The cell plasm plays an active though not an exclusive part in the specialisation; for as the nucleus influences nutrition and secretion, it acts as a factor in the differentiation of the tissues. When tissues so diverse in character as muscular fibre, cartilage, fibrous tissues, and bone arise from the cells of the middle or mesoblast layer, it is obvious that, in addition to the morphological differentiation affecting form and structure, a chemical differentiation affecting composition also occurs, as the result of which a physiological differentiation takes place. Corresponding differentiations also modify the cells of the outer and inner layers. The tissues and organs become fitted to transform the energy derived from the food into muscular energy, nerve energy, and other forms of vital activity. Hence the study of the development of the generalised cell layers in the young embryo enables us to realise how all the complex constituent parts of the body in the higher animals and in man are evolved by the process of cell growth and differentiation from a simple nucleated cell—the fertilised ovum. A knowledge of the cell and of its life-history is therefore the foundation-stone on which biological science in all its departments is based.

If we are to understand by an organ in the biological sense a complex body capable of carrying on a natural process, a nucleated cell is an organ in its simplest form. In a unicellular animal or plant such an organ exists in its most primitive stage. The higher plants and animals again are built up of multitudes of these organs, each of which, whilst having its independent life, is associated with the others, so that the whole may act in unison for a common purpose. As in one of your great factories each spindle is engaged in twisting and winding its own thread, it is at the same time intimately associated with the hundreds of other spindles in its immediate proximity, in the manufacture of the yarn from which the web of cloth is ultimately to be woven.

It has taken more than fifty years of hard and continuous work to bring our knowledge of the structure and development of the tissues and

organs of plants and animals up to the level of the present day. Amidst the host of names of investigators, both at home and abroad, who have contributed to its progress, it may seem invidious to particularise individuals. There are, however, a few that I cannot forbear to mention, whose claim to be named on such an occasion as this will be generally conceded.

Botanists will, I think, acknowledge Wilhelm Hofmeister as a master in morphology and embryology, Julius von Sachs as the most important investigator in vegetable physiology during the last quarter of the century, and Strasburger as a leader in the study of the phenomena of nuclear division.

The researches of the veteran Professor of Anatomy in Würzburg, Albert von Kölliker, have covered the entire field of animal histology. His first paper, published fifty-nine years ago, was followed by a succession of memoirs and books on human and comparative histology and embryology, and culminated in his great treatise on the structure of the brain, published in 1896. Notwithstanding the weight of more than eighty years, he continues to prosecute histological research, and has published the results of his latest, though let us hope not his last, work during the present year.

Amongst our own countrymen, and belonging to the generation which has almost passed away, was William Bowman. His investigations between 1840 and 1850 on the mucous membranes, muscular fibre, and the structure of the kidney, together with his researches on the organs of sense, were characterised by an acuteness of observation and of interpreting difficult and complicated appearances which has made his memoirs on these subjects landmarks in the history of histological inquiry.

Of the younger generation of biologists Francis Maitland Balfour, whose early death is deeply deplored as a loss to British science, was one of the most distinguished. His powers of observation and philosophic perception gave him a high place as an original inquirer, and the charm of his personality—for charm is not the exclusive possession of the fairer sex—endeared him to his friends.

General Morphology.

Along with the study of the origin and structure of the tissues of organised bodies, much attention has been given during the century to the parts or organs in plants and animals, with the view of determining where and how they take their rise, the order of their formation, the changes which they pass through in the early stages of development, and their relative positions in the organism to which they belong. Investigations on these lines are spoken of as morphological, and are to be distinguished from the study of their physiological or functional relations, though both are necessary for the full comprehension of the living organism.

The first to recognise that morphological relations might exist between the organs of a plant, dissimilar as regards their function, was the poet Goethe, whose observations, guided by his imaginative faculty, led him to declare that the calyx, corolla, and other parts of a flower, the scales of a bulb, &c., were metamorphosed leaves, a principle generally accepted by botanists, and indeed extended to other parts of a plant, which are referred to certain common morphological forms although they exercise different functions. Goethe also applied the same principle in the study of the skeletons of vertebrate animals, and he formed the opinion that the spinal column and the skull were essentially alike in construction, and consisted of vertebræ, an idea which was also independently conceived and advocated by Oken.

The anatomist who in our country most strenuously applied himself to the morphological study of the skeleton was Richard Owen, whose knowledge of animal structure, based upon his own dissections, was unrivalled in range and variety. He elaborated the conception of an ideal, archetype vertebrate form which had no existence in nature, and to which, subject to modifications in various directions, he considered all vertebrate skeletons might be referred. Owen's observations were conducted to a large extent on the skeletons of adult animals, of the knowledge of which he was a master. As in the course of development modifications in shape and in the relative position of parts not unfrequently occur and their original character and place of origin become obscured, it is difficult, from the study only of adults, to arrive at a correct interpretation of their morphological significance. When the changes which take place in the skull during its development, as worked out by Reichert and Rathke, became known and their value had become appreciated, many of the conclusions arrived at by Owen were challenged and ceased to be accepted. It is, however, due to that eminent anatomist to state from my personal knowledge of the condition of anatomical science in this country fifty years ago, that an enormous impulse was given to the study of comparative morphology by his writings, and by the criticisms to which they were subjected.

There can be no doubt that generalised arrangements do exist in the early embryo which, up to a certain stage, are common to animals that in their adult condition present diverse characters, and out of which the forms special to different groups are evolved. As an illustration of this principle, I may refer to the stages of development of the great arteries in the bodies of vertebrate animals. Originally, as the observations of Rathke have taught us, the main arteries are represented by pairs of symmetrically arranged vascular arches, some of which enlarge and constitute the permanent arteries in the adult, whilst others disappear. The increase in size of some of these arches, and the atrophy of others, are so constant for different groups that they constitute anatomical features as distinctive as the modifications in the skeleton itself. Thus in mammals the fourth vascular arch on the left side persists, and forms the arch

of the aorta; in birds the corresponding part of the aorta is an enlargement of the fourth right arch, and in reptiles both arches persist to form the great artery. That this original symmetry exists also in man we know from the fact that now and again his body, instead of corresponding with the mammalian type, has an aortic arch like that which is natural to the bird, and in rarer cases even to the reptile. A type form common to the vertebrata does therefore in such cases exist, capable of evolution in more than one direction.

The reputation of Thomas Henry Huxley as a philosophic comparative anatomist rests largely on his early perception of, and insistence on, the necessity of testing morphological conclusions by a reference to the development of parts and organs, and by applying this principle in his own investigations. The principle is now so generally accepted by both botanists and anatomists that morphological definitions are regarded as depending essentially on the successive phases of the development of the parts under consideration.

The morphological characters exhibited by a plant or animal tend to be hereditarily transmitted from parents to offspring, and the species is perpetuated. In each species the evolution of an individual, through the developmental changes in the egg, follows the same lines in all the individuals of the same species, which possess therefore in common the features called specific characters. The transmission of these characters is due, according to the theory of Weismann, to certain properties possessed by the chromosome constituents of the segmentation nucleus in the fertilised ovum, named by him the germ plasm, which is continued from one generation to another, and impresses its specific character on the egg and on the plant or animal developed from it.

As has already been stated, the special tissues which build up the bodies of the more complex organisms are evolved out of cells which are at first simple in form and appearance. During the evolution of the individual, cells become modified or differentiated in structure and function, and so long as the differentiation follows certain prescribed lines the morphological characters of the species are preserved. We can readily conceive that, as the process of specialisation is going on, modifications or variations in groups of cells and the tissues derived from them, notwithstanding the influence of heredity, may in an individual diverge so far from that which is characteristic of the species as to assume the arrangements found in another species, or even in another order. Anatomists had indeed long recognised that variations from the customary arrangement of parts occasionally appeared, and they described such deviations from the current descriptions as irregularities.

Darwinian Theory.

The signification of the variations which arise in plants and animals had not been apprehended until a flood of light was thrown on the entire

subject by the genius of Charles Darwin, who formulated the wide-reaching theory that variations could be transmitted by heredity to younger generations. In this manner he conceived new characters would arise, accumulate, and be perpetuated, which would in the course of time assume specific importance. New species might thus be evolved out of organisms originally distinct from them, and their specific characters would in turn be transmitted to their descendants. By a continuance of this process new species would multiply in many directions, until at length from one or more originally simple forms the earth would become peopled by the infinite varieties of plant and animal organisms which have in past ages inhabited, or do at present inhabit, our globe. The Darwinian theory may therefore be defined as Heredity modified and influenced by Variability. It assumes that there is an heredity quality in the egg which, if we take the common fowl for an example, shall continue to produce similar fowls. Under conditions, of which we are ignorant, which occasion molecular changes in the cells and tissues of the developing egg, variations might arise, in the first instance probably slight, but becoming intensified in successive generations, until at length the descendants would have lost the characters of the fowl and have become another species. No precise estimate has been arrived at, and indeed one does not see how it is possible to obtain it, of the length of years which might be required to convert a variation, capable of being transmitted, into a new and definite specific character.

The circumstances which, according to the Darwinian theory, determined the perpetuation by hereditary transmission of a variety and its assumption of a specific character depended, it was argued, on whether it possessed such properties as enabled the plant or animal in which it appeared to adapt itself more readily to its environment, *i.e.* to the surrounding conditions. If it were to be of use the organism in so far became better adapted to hold its own in the struggle for existence with its fellows and with the forces of nature operating on it. Through the accumulation of useful characters the specific variety was perpetuated by natural selection so long as the conditions were favourable for its existence, and it survived as being the best fitted to live. In the study of the transmission of variations which may arise in the course of development it should not be too exclusively thought that only those variations are likely to be preserved which can be of service during the life of the individual, or in the perpetuation of the species, and possibly available for the evolution of new species. It should also be kept in mind that morphological characters can be transmitted by hereditary descent, which, though doubtless of service in some bygone ancestor, are in the new conditions of life of the species of no physiological value. Our knowledge of the structural and functional modifications to be found in the human body, in connection with abnormalities and with tendencies or predisposition to diseases of various kinds, teaches us that

characters which are of no use, and indeed detrimental to the individual, may be hereditarily transmitted from parents to offspring through a succession of generations.

Since the conception of the possibility of the evolution of new species from pre-existing forms took possession of the minds of naturalists, attempts have been made to trace out the lines on which it has proceeded. The first to give a systematic account of what he conceived to be the order of succession in the evolution of animals was Ernst Haeckel, of Jena, in a well-known treatise. Memoirs on special departments of the subject, too numerous to particularise, have subsequently appeared. The problem has been attacked along two different lines: the one by embryologists, of whom may be named Kowalewsky, Gegenbaur, Dohrn, Ray Lankester, Balfour, and Gaskell, who with many others have conducted careful and methodical inquiries into the stages of development of numerous forms belonging to the two great divisions of the animal kingdom. Invertebrates, as well as vertebrates, have been carefully compared with each other in the bearing of their development and structure on their affinities and descent, and the possible sequence in the evolution of the Vertebrata from the Invertebrata has been discussed. The other method pursued by palæontologists, of whom Huxley, Marsh, Cope, Osborne, and Traquair are prominent authorities, has been the study of the extinct forms preserved in the rocks and the comparison of their structure with each other and with that of existing organisms. In the attempts to trace the line of descent the imagination has not unfrequently been called into play in constructing various conflicting hypotheses. Though from the nature of things the order of descent is, and without doubt will continue to be, ever a matter of speculation and inference and not of demonstration, the study of the subject has been a valuable intellectual exercise and a powerful stimulant to research.

We know not as regards time when the fiat went forth, 'Let there be Life, and there was Life.' All we can say is that it must have been in the far-distant past, at a period so remote from the present that the mind fails to grasp the duration of the interval. Prior to its genesis our earth consisted of barren rock and desolate ocean. When matter became endowed with Life, with the capacity of self-maintenance and of resisting external disintegrating forces, the face of nature began to undergo a momentous change. Living organisms multiplied, the land became covered with vegetation, and multitudinous varieties of plants, from the humble fungus and moss to the stately palm and oak, beautified its surface and fitted it to sustain higher kinds of living beings. Animal forms appeared, in the first instance simple in structure, to be followed by others more complex, until the mammalian type was produced. The ocean also became peopled with plant and animal organisms, from the microscopic diatom to the huge leviathan. Plants and animals acted and

reacted on each other, on the atmosphere which surrounded them and on the earth on which they dwelt, the surface of which became modified in character and aspect. At last Man came into existence. His nerve-energy, in addition to regulating the processes in his economy which he possesses in common with animals, was endowed with higher powers. When translated into psychical activity it has enabled him throughout the ages to progress from the condition of a rude savage to an advanced stage of civilisation ; to produce works in literature, art, and philosophy which have exerted, and must continue to exert, a lasting influence on the development of his higher Being ; to make discoveries in natural and physical science ; to acquire a knowledge of the structure of the earth, of the ocean in its changing aspects, of the atmosphere and the stellar universe, of the chemical composition and physical properties of matter in its various forms, and to analyse, comprehend, and subdue the forces of nature.

By the application of these discoveries to his own purposes Man has, to a large extent, overcome time and space ; he has studded the ocean with steamships, girdled the earth with the electric wire, tunnelled the lofty Alps, spanned the Forth with a bridge of steel, invented machines and founded industries of all kinds for the promotion of his material welfare, elaborated systems of government fitted for the management of great communities, formulated economic principles, obtained an insight into the laws of health, the causes of infective diseases, and the means of controlling and preventing them.

When we reflect that many of the most important discoveries in abstract science and in its applications have been made during the present century, and indeed since the British Association held its first meeting in the ancient capital of your county sixty-nine years ago, we may look forward with confidence to the future. Every advance in science provides a fresh platform from which a new start can be made. The human intellect is still in process of evolution. The power of application and of concentration of thought for the elucidation of scientific problems is by no means exhausted. In science is no hereditary aristocracy. The army of workers is recruited from all classes. The natural ambition of even the private in the ranks to maintain and increase the reputation of the branch of knowledge which he cultivates affords an ample guarantee that the march of science is ever onwards, and justifies us in proclaiming for the next century, as in the one fast ebbing to a close, that Great is Science, and it will prevail.

REPORTS

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Meteorological Observatory, Montreal.—Report of the Committee, consisting of Professor H. L. CALLENDAR (*Chairman*), Professor C. McLEOD (*Secretary*), Professor F. ADAMS, *and* Mr. R. F. STUPART, *appointed for the purpose of establishing a Meteorological Observatory on Mount Royal, Montreal.*

[PLATE I.]

THE following preliminary report has been received from the observers :—

The difference of temperature between the College Observatory and the top of Mount Royal is continuously recorded by means of a Callendar Electric Recorder and a pair of differential platinum thermometers. The thermometers are of the usual pattern, giving a change of 2 ohms for 100° Fahr., and the scale of the record is one-fifth of an inch to the degree Fahr. By a simple change in the connections the actual temperature at either station can be recorded separately instead of the difference of temperature between the two. The thermometer at the top of the mountain is placed on a platform 50 feet above the ground and 850 feet above sea level. The other thermometer is at a height of 4 feet above the ground, and 180 feet above sea level. The distance between the two is rather more than a mile. The recorder is placed in the College Observatory at the lower station, and is connected to the distant thermometer by four separate lines of No. 12 copper wire erected on poles with glass insulators, and covered with weather-proof insulation ordinarily used for telephone work. The recorder is of the original Callendar pattern, and was made at the McDonald Physics Building in 1897.

The line to the mountain has been broken by storm on several occasions ; parts of it have sometimes been carried away by thieves ; on one occasion the line was struck by lightning, the thermometers were destroyed, and the instrument burnt out ; on another occasion the instrument was burnt out through an accidental short circuit of the electric lighting current. The original thermometers which were damaged by lightning have been replaced by new and improved instruments, and all other damages have been repaired, so that the whole apparatus is at present in good running condition. Great delay has been caused by these accidents ; and this, coupled with pressure of other work on the observers, has made it impossible to secure up to the present date a sufficiently extended series

of observations to be of value for the general discussion of results. To show the nature of the records, and the working of the apparatus, a sample record sheet for August 21, 22, 1900, including a zero test and two comparisons with mercury thermometers, which were read simultaneously at the two stations by separate observers, is given herewith. (Plate I.)

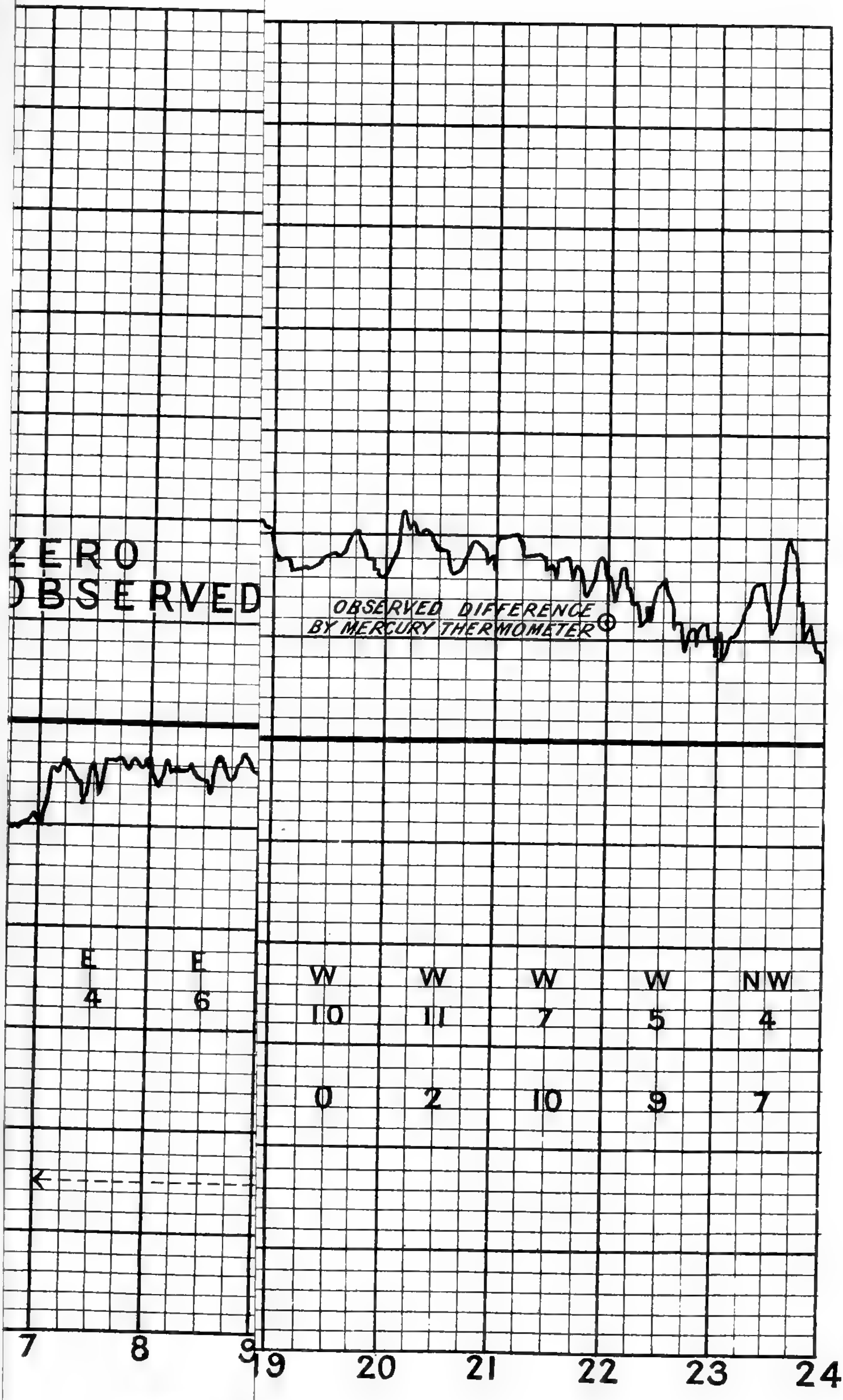
The zero line on the chart was obtained by placing the thermometers at the two stations in melting ice simultaneously, and allowing them to remain for about an hour at this temperature. The differences between the simultaneous readings of the mercury thermometers at the two stations were plotted from this zero line, and show a very satisfactory agreement with the differential platinum thermometers, considering the continual variations of temperature and the difference in sensibility of the two instruments. The direction of the wind and the velocity in miles per hour are recorded by instruments placed on the summit and connected by lines to the electrical recording apparatus in the College Observatory at the lower station. The record for August 21, 22 exhibits a complete revolution in the direction of the wind from N.W. through E. and S. and back to N.W. These changes in the direction of the wind frequently appear to be related to the changes in the difference of temperature. The amount of sunshine in tenths per hour recorded at the College Observatory is also marked on the charts, and the general weather conditions prevailing.

The apparatus as at present arranged gives admirable results in fair weather, but it has been found impossible to preserve the insulation of the line during rain. This has steadily deteriorated since its erection, and the results cannot now be relied on when the rainfall is considerable, or for short periods after. This is unfortunate, as it would be interesting to study the changes of temperature occurring with the onset of rain. To completely obviate the insulation defects in bad weather, and to protect the line from thieves and lightning, it would be necessary to replace the present pole line with a lead-covered cable buried in the ground. It is hardly necessary to say that this was foreseen at the time when the line was originally projected, as all installations of platinum thermometers up to that date had been provided with lead-covered cables, especially in cases where the distance involved was considerable. The original estimate of 100*l.* for the apparatus was based on the assumption of a lead-covered cable. But when the British Association in 1897 were unable to grant more than 50*l.*, it was decided to utilise the existing pole line rather than abandon the project entirely. There is still some hope that the necessary funds may be forthcoming for the replacement of the existing line by a cable; but until this necessary improvement is effected it is feared that the scientific value of the work must be seriously impaired.

Electrolysis and Electro-chemistry.—Report of the Committee, consisting of Mr. W. N. SHAW (*Chairman*), Mr. E. H. GRIFFITHS, Rev. T. C. FITZPATRICK, Mr. S. SKINNER, *and* Mr. W. C. D. WHETHAM (*Secretary*), *appointed to report on the Present State of our Knowledge in Electrolysis and Electro-chemistry.*

THE experiments on the conductivity of dilute aqueous solutions of salts and acids at the freezing point have been completed by Mr. Whetham,

ollege Observatory, Re



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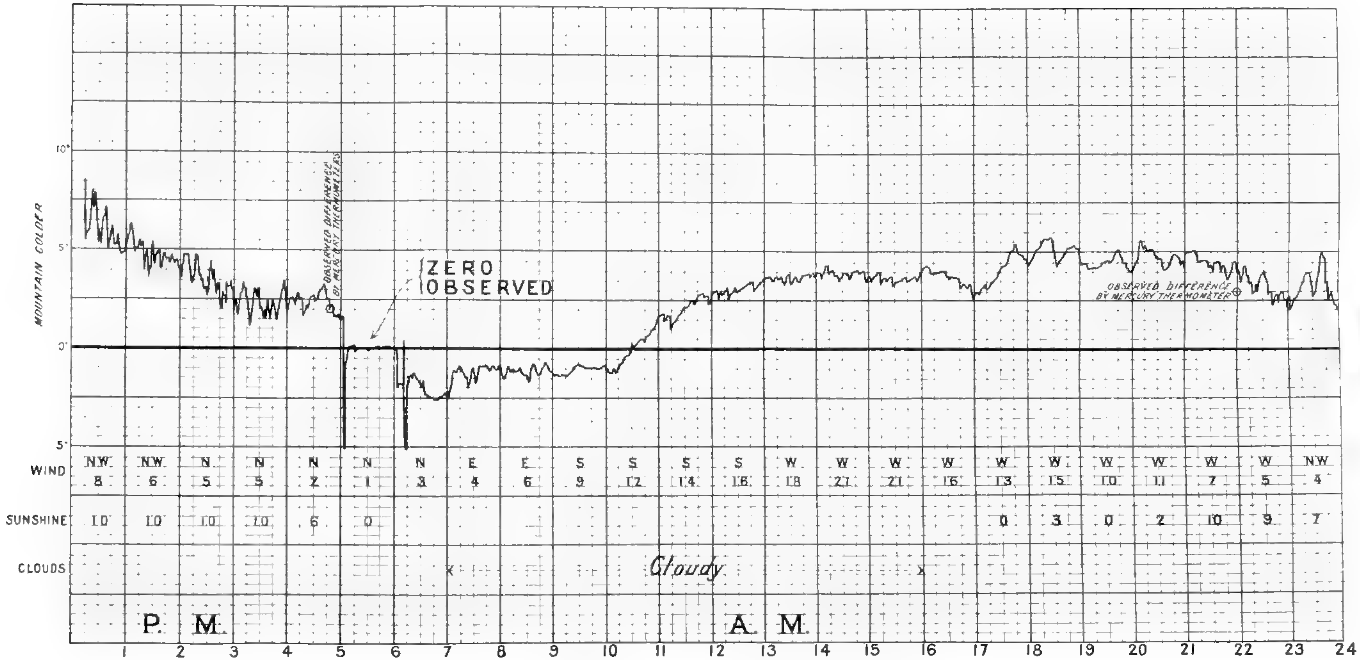
McGill College Observatory, Record of difference of Temperature between Mount Royal and College, Aug. 21 & 22, 1900.



Illustrating the Report on the Meteorological Observatory on Mount Royal, Montreal.

and the full results published in the 'Philosophical Transactions of the Royal Society of London,' series A, vol. cxciv. 1900, p. 321. Curves and tables are given showing the values obtained for the ionisation. The measurements of the freezing points of the same solutions, undertaken by Mr. Griffiths, are still in progress. It is hoped that his results will soon be ready, and that a useful comparison of the two lines of research may then be made.

The consumption of a carbon anode in electrolysis has formed the subject of some experiments by another member of the Committee, Mr. Skinner.[1] Carbon electrodes are used in many electrotechnical processes, and their solution and disintegration form one of the chief difficulties to be overcome. It appears that whenever a highly oxidised product undergoes electrolytic decomposition the anion gives, directly or indirectly, a considerable quantity of carbonic acid. The experiments show that as much as 85 per cent. of the escaping gases consists of carbon dioxide when a solution of potassium permanganate is the electrolyte.

Since the publication in 1897 of the Committee's Report on the Theory of the Migration of Ions and of Specific Ionic Velocities, an important paper by Orme Masson has appeared,[2] giving an account of an experimental method of measuring ionic velocities and of the results for a number of ions.

The original plan of the Committee, as arranged in 1890, included reports on the following additional sections :—§ *d.* Electro-chemical Thermo-dynamics ; § *e.* Electric Endosmose ; and § *g.* Numerical Relations. Information on some of these sections has already been made easily accessible.

A small book,' 'Das Leitvermögen der Electrolyte,' Leipzig, 1898, has been published by Dr. von Kohlrausch and Dr. Holborn, giving a complete account of the method of measuring electrolytic conductivity by means of alternating currents in conjunction with a telephone, with the precautions necessary for accurate results. There are also tables of the conductivity of certain solutions, which may be used to standardise resistance vessels.

The thermo-dynamics of electrolytic processes is in some degree covered by a Report by Professor E. F. J. Love on our Knowledge of the Thermo-dynamics of the Voltaic Cell, published by the Australasian Association for the Advancement of Science, Sydney, 1898.

Since the original appointment of the Committee, very many and important researches upon the chemical phenomena resulting from or associated with the passage of electricity through gases have been published.

In order to make the Committee's Report in any way a complete sketch of the subject of electro-chemistry as now developed, its scope would have to be enlarged to include such phenomena as the conductivity of gases at high temperatures, and under the influence of other ionising agencies. The Committee feel unable to undertake such an extension of their work, and do not seek reappointment.

[1] *Proc. Camb. Phil. Soc.*, x. 261, 1900.
[2] *Phil. Trans.*, A, cxciii., 1899.

On Solar Radiation.—Report of the Committee, consisting of Dr G. JOHNSTONE STONEY (*Chairman*), Professor H. McLEOD (*Secretary*), Sir G. G. STOKES, Professor A. SCHUSTER, Sir H. E. ROSCOE, Captain Sir W. DE W. ABNEY, Dr. C. CHREE, Professor G. F. FITZGERALD, Professor H. L. CALLENDAR, Mr. W. E. WILSON, and Professor A. A. RAMBAUT, *appointed to consider the best Methods of Recording the Direct Intensity of Solar Radiation. (Drawn up by* Professor H. L. CALLENDAR.)

As already reported, the copper-cube actinometer constructed for this Committee, and described in the Report for 1886, was entrusted to Professor Callendar in August 1899 for comparison with his automatic recording instrument described in the Report for 1898. In the course of the past year a number of experiments have been made with this apparatus by Miss W. E. Walker, 1851 Exhibition Scholar, working at University College, London, under the direction of Professor Callendar. The object of the work was to obtain absolute measurements of radiation for the calibration of the more convenient form of continuous recorder. In its original form the copper-cube actinometer was not very well adapted, and probably was not intended, for absolute measurements; but with some modifications very promising results have been already obtained, and it is believed that the method thus modified will lead to trustworthy and valuable determinations.

The history of the copper-cube actinometer is contained in various reports communicated by this committee, of which the following is a brief summary. The method originally proposed was to concentrate the rays of the sun by means of a lens through a hole in one side of the cube on to a central mercury thermometer with a flat bulb. The steady difference of temperature between the central thermometer and the walls of the cube would be approximately proportional to the intensity of solar radiation, and might be taken as a measure of the same in arbitrary units. To obtain the equivalent in absolute measure it would be necessary to know the rate of cooling of the thermometer and the coefficient of absorption of the bulb and of the lens by which the rays were concentrated These might have been obtained by auxiliary experiments on the rate of heating or cooling under various conditions; but as the mercury thermometers proved unsuitable in many respects, the apparatus was subsequently modified by the substitution of a copper disc and a thermo-junction for the central thermometer. This permitted the observation of smaller differences of temperature and the more accurate determination of the thermal capacity of the irradiated disc.

The elementary theory of the instrument, assuming that for small differences of temperature the rate of cooling of the disc would be proportional to the difference of temperature between the disc and the walls of the cube, was given in the Report of the Committee for 1892. If θ is the excess of temperature of the disc over the enclosure at any time t measured from the commencement of the exposure to the radiation to be measured, and if r be the initial rate of rise of temperature of the disc in

degrees per second, and $q\theta$ the rate of fall of temperature at any excess θ if the radiation were cut off, we have evidently the equation

$$d\theta/dt = r - q\theta \quad . \quad . \quad . \quad . \quad . \quad (1)$$

the solution of which under the given initial conditions is

$$\theta = (1 - e^{-qt})r/q \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The limiting steady temperature of the disc when t is infinite is $\theta^{\circ} = r/q$.

In 1893 some experiments were recorded verifying the elementary theory and the constancy of the coefficient of cooling q. In 1896 a photographic recording device was applied to obtain the curves of heating of the disc by registering the deflections of the D'Arsonval galvanometer on a moving photographic plate. The curves proved to be approximately logarithmic, but the reduction of the results to absolute measure was not attempted.

Absolute Measurements.—If I be the intensity of radiation to be measured in watts per square centimetre, and A be the area in square centimetres normal to the rays over which the measured portion of the radiation is incident, the quantity of heat received is IA joules per second. This is equal to $r\mathrm{J}ms$, where r as already defined is the initial rate of rise of temperature of the disc when exposed to the radiation, J is the number of joules in one calorie, which may be taken as approximately 4·18 ; m is the mass, and s the specific heat of the disc. In applying this method it is tacitly assumed that the whole of the disc is at a uniform temperature θ at any moment during the rise of temperature ; it is also necessary to know accurately the specific heat s of the material of the disc, and to be able to calibrate the thermo-junction so as to interpret the indications of the galvanometer in degrees of temperature. Further, the rise of temperature must not exceed two or three degrees in order that q, the coefficient of cooling, may be taken as constant, and the rate of rise must be sufficiently slow to permit of accurate measurement, and of the uniform diffusion of heat throughout the disc.

After some preliminary experiments with the apparatus it became evident that these conditions were not sufficiently satisfied by the disc and thermo-junction employed in the experiments already recorded. The disc was about two centimetres in diameter and half a millimetre thick. The aperture for admitting the radiation was about one centimetre. Under these conditions it was not possible without the use of lenses to ensure a sufficiently uniform distribution of the radiation over the surface of the disc, and the rate of rise of temperature was too rapid for accurate measurement. The disc was supported on a short iron wire nearly two millimetres thick, which conducted heat away from the centre of the disc so rapidly that the temperature of the junction was always very considerably below that of the disc. Owing to its form the thermo-junction could not be accurately calibrated, and the sensitiveness of the copper-iron couple, though suitable for powerful sources such as direct solar radiation, was far too small for accurate work with sources of constant intensity such as were required for absolute measurement.

The Galvanometer supplied with the instrument was of the Ayrton Mather type, with a resistance of about 7·5 ohms, and gave a deflection of about 2 millimetres at 1 metre per microvolt, equivalent to about 20 millimetres per degree with a copper-iron junction. In order to

increase the accuracy of reading, a good plane mirror was substituted for the original concave mirror, and observations were taken with a telescope and scale at a distance of about 3 metres. The definition of the image was such as to permit of reading with accuracy to a fifth of a millimetre. Owing to the gradual change or 'drift' of zero, due to imperfect elasticity of the suspension, which is always a serious source of error in galvanometers of this type, it was found to be impossible to obtain sufficiently consistent observations by the deflection method. To minimise this source of error the potentiometer balance-method was adopted, and care was taken not to subject the suspension to excessive torsion. To increase the sensitiveness, the iron-copper thermo-junction was replaced by junctions of iron and german silver (30 microvolts per degree), and iron and constantan (52 microvolts). The wires employed for this purpose were very fine—about 0·2 millimetre—to minimise the cooling of the junctions by conduction, and their thermo-electric powers were determined by a special series of observations made on the particular pieces employed. With these improvements it was optically possible to observe a difference of temperature of a thousandth of a degree with certainty, as it corresponded to a deflection of about a quarter of a millimetre with the iron and constantan couple.

Thermo-electric Sources of Error.—In observing small differences of temperature with a thermo-couple, assuming that drift of the galvanometer zero is avoided by employing the balance method, the most troublesome residual errors arise from accidental thermal effects due to small differences of temperature in other parts of the electric circuit, and in particular at the junctions of the bridge-wire, and at the point of contact of the slider. It is usual to employ german-silver or platinoid or platinum silver as the material for the bridge-wire to secure a low temperature-coefficient and high specific resistance. Unfortunately these materials give large thermal effects when joined to copper. The alloy known as manganin is greatly to be preferred to platinoid or constantan in this respect, but its surface is more liable to tarnish. The superiority of the bolometric method (platinum resistance) over the thermo-couple for accurate measurement of small differences of temperature depends chiefly on the relative ease with which these accidental thermal effects may be eliminated. In the present instance they were found to be so troublesome that it was eventually decided to make the bridge-wire and the whole of the circuit, with the exception of the couple itself, of pure copper. By adopting this method the accidental disturbances were reduced to a small fraction of a microvolt, without taking any special precautions to secure uniformity of temperature throughout the various parts of the measuring apparatus. The cold junctions of the thermo-couple were contained in a copper plug screwing into the copper cube, and were assumed to be at the same temperature as the walls of the cube. In order to secure this, and to minimise changes of temperature of the copper cube, it was found necessary to wrap the cube and the projecting plug in a considerable thickness of cotton-wool, even when exposed to feeble sources of radiation. The layer of felt surrounding the cube formed no protection for the copper plug containing the cold junction, and proved quite inadequate to prevent rapid changes of temperature when exposed to strong sources.

Constant Source of Radiation.—The necessity of a constant source of radiation for comparative measurements and tests was recognised at a

very early period in the experiments. The first attempt at a constant source was an Argand burner with a very delicate pressure regulator, a given area of the brightest part of the flame being selected as the source. This proved to be a very good method of testing the variations in the quality of the gas, but had to be abandoned as a constant source of radiation. It was also objectionable on account of the difficulty of keeping the glass chimney uniformly clean, and because the excessive amount of heat generated disturbed the experimental conditions, and the gas fumes had the effect of tarnishing the contacts of the electrical apparatus and the metallic plates used as reflectors. A pair of one hundred candle-power focus-lamps were then obtained from the Ediswan Company. These were designed to work on a pressure of 90 volts at an efficiency of about 3·6 watts per candle, and a current of 4 amperes. They were spherical in form and silvered on one half, which had the effect of nearly doubling the radiating power for a given current, while at the same time it ensured an almost perfect constancy in the proportion of radiation reflected from the rear of the source, which had proved a difficulty with the Argand burner. When used as constant sources of radiation the lamps were worked at a pressure of only 75 volts and a current of about three amperes, supplied by a large storage battery of forty-four cells. The battery was not used for any other purpose while the experiments were in progress, and was capable of maintaining the required pressure constant to a tenth of a volt for several hours under suitable conditions of charge. The pressure on the lamps was regulated and recorded during the experiments by means of an automatic recording potentiometer working on a scale of one inch to the volt. The readings of this instrument were adjusted by means of a Clark cell, and were accurate to about one part in 5,000. One of the focus-lamps was set apart as a standard, and was used only for occasional comparisons. When working at a voltage so far below that for which they were designed, the lamps were found to remain exceedingly constant. In the course of six months' work the lamp in regular use did not vary with respect to the standard by more than one per cent., and its variations over short periods could easily have been controlled and corrected if the accuracy so far attained in the radiation measurements had made the application of such a correction desirable. The area of the incandescent grid was about one square inch, and the diameter of the bulb four and a half inches. The lamp was set to shine through an aperture of its own diameter in a double tin-plate screen, so as to include the whole of the radiation from the heated glass, but to exclude as far as possible radiation from the base of the lamp and heated objects in its immediate neighbourhood. This precaution was particularly important in comparing the indications of the tube form of radio-calorimeter with those to the bolometric sunshine receiver intended for the direct exposure of solar radiation, as the latter instrument was not provided with a screen and diaphragms for excluding lateral radiation, but was intended to integrate the vertical component of the whole radiation from the sky as well as that from the sun.

Determination of the Initial Rate of Heating of the Disc.—To ensure uniformity of temperature of the disc, and a sufficiently slow rate of heating, it was found necessary to replace the original disc by a much thicker disc the size of which was chosen to be just sufficient to catch the whole of the rays incident on the aperture. Before commencing an observation, the reading of the galvanometer was observed with the slider at the zero of

the bridge-wire in order to allow for any minute residual difference of temperature between the cube and the disc when the apparatus was screened from radiation. The time of exposure was recorded on an electric chronograph by the dropping of the screen on a suitable key. The sliding contact was then shifted to successive points on the bridge-wire, and the moment of balance at each point was observed and recorded on the chronograph. These observations were continued for about five minutes, or as long as the rise continued sufficiently rapid. Occasional observations were then made to determine the final steady difference of temperature $\theta°$ during the next fifteen minutes, after which the temperature remained steady.

The following is a sample of observations taken with the copper-cube :

Date, April 4, 1900. *Observer*, Miss W. E. WALKER.

Temperature of Clark cell, 19·0° C. ; bridge-wire, 20·2° C. ; resistance per cm. of B.W., ·001091 ohm ; P.D. per cm., ·7795 microvolt ; diameter of disc, 1·40 cm. ; diameter of aperture in cube, 1·00 cm. ; distance of lamp from aperture, 60·0 cms. ; volts on lamp, 77·2 ; mass of copper disc, 0·8320 gramme ; $Jms/A = \cdot 4206$.

—	Bridge Reading	Time t	Temperature θ	q	r	I
(1)	39·8	76·56	·5966	·01036	·01129	·00475
(2)	59·8	159·35	·8964	·01084	·01182	·00497
(3)	72·9	Steady	$1{\cdot}090 = \theta°$	$= r/q$	—	—

Solution of the Equations.—Assuming the elementary theory of the method as given by equation (2), the simplest method of procedure is to take the value of the ratio r/q as given by the final steady difference of temperature $\theta° = 1{\cdot}090$, and to calculate the values of q from the intermediate observations of t and θ by substituting the observed value of r/q in equation (2). We thus obtain

$$qt = 2{\cdot}3026 \log_{10} \theta°/(\theta° - \theta) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The value of r is then found by the relation $r = q\theta$, and the intensity of radiation I by multiplying r by the constant factor $Jms/A = \cdot 4206$. The values thus obtained are given in the columns headed q, r, I. They invariably exhibited a progressive increase with the time. The value of q could also be found by eliminating the ratio r/q between any two observations, and solving the equation by trial for q. Taking the observations (1) and (2) at 39·8 and 59·8 cms. above given, we thus obtain $q = \cdot 00967$, whence $r = \cdot 01103$, and $I = \cdot 00464$, which illustrate the same tendency, being smaller than the results obtained by assuming the ratio of r to q from the final steady temperature. The focus-lamp in this experiment was set to shine through an aperture of nearly the same size as the incandescent grid, but this was found to be unsatisfactory, as the field of illumination was not sufficiently uniform for the bolometric receivers. This consideration, among others, ultimately necessitated the abandonment of the aperture method of limiting the radiation received by the disc.

Effects of Lag.—It was clear from the results above quoted, and from a number of others obtained with the same apparatus with different discs

at different distances and different rates of heating, that the equations already given did not satisfactorily represent the observations. In considering the possible sources of constant error inherent in the method, it seemed unlikely that the assumption that the rate of loss of heat was proportional to the difference of temperature (q constant) could be seriously in error, as the whole difference of temperature did not exceed one or two degrees. The most probable explanation of the discrepancy appeared to be that time was required for the uniform distribution of heat through the disc, and that the indications of the thermo-junction were retarded by conduction of heat along the wires, and by lag in the movement of the galvanometer coil, which was necessarily very dead-beat when short-circuited on the couple. These various sources of error could all be approximately represented by assuming a constant time-lag in the readings; a type of error which was necessarily inherent in the method, and could not have been detected by the experiments recorded in 1896. In order to eliminate the time-lag from the equations, it is only necessary to take two observations in addition to the final steady temperature. If we write the equations in the form (3) already given, and take the difference, we thus obtain

$$q\,(t''-t')=2{\cdot}3026\,\log_{10}(\theta^{\circ}-\theta')/(\theta^{\circ}-\theta'') \qquad . \quad . \quad (4)$$

Treating the observations already given in this manner we find

$q={\cdot}01130$. $r={\cdot}01232$. $\mathrm{I}={\cdot}00518$. Time-lag$=6{\cdot}45$ secs.

With only three observations it is of course always possible to calculate a value of the lag to satisfy the readings exactly, but it appeared that a similar assumption satisfied the observations within the probable limits of error in those cases also in which a larger number of readings were taken.

Defects of the Copper-cube Actinometer.—The excessive value of the time-lag observed in the observations with this apparatus appeared to be partly due to the impossibility of securing uniform illumination of the disc by the aperture method. It was necessary that the disc should be large enough to catch the whole of the radiation passing through the aperture in the cube, and this could not be secured without leaving a considerable margin at the edge of the disc which was either not illuminated at all, or only partly illuminated by the penumbra of the aperture. With the lamp at 60 cms. it was necessary to use a disc 1·40 cm. in diameter for an aperture of 1·00 cm. diameter. This was the more necessary because the construction of the apparatus, and the method of screwing in the copper plug by which the disc was supported, made it extremely difficult to centre the disc accurately, and to direct it so as to receive the rays normally and centrally. Another serious defect to which allusion has already been made, was the variation of temperature of the cube and the copper plug, which although greatly reduced was not entirely eliminated by the cotton-wool wrappings. For these and other reasons it was decided to design a new form of actinometer for the application of the same method in a manner more convenient for laboratory use.

Tube-form of Radio-calorimeter.—The terms 'actinometer,' 'bolometer,' and 'radio-micrometer,' which are otherwise suitable for instruments of this class, have acquired special significations, and are in general use for instruments which are not designed for absolute measurements,

It appears therefore preferable to use the more general term 'radio-calorimeter' for this particular instrument, as it was not intended, like the 'pyrheliometers' of Pouillet or Ångström, for the direct measurement of solar radiation. The tube-form of radio-calorimeter consists of a pair of concentric tubes about nine inches long separated by an annular space of about a twentieth of an inch, through which water is caused to circulate in a spiral fashion by a helix of copper wire nearly fitting the space between the tubes. The inner tube has a diameter of about one inch, and is furnished with a series of sliding copper diaphragms, which can be set at suitable points to screen off any lateral radiation, and prevent internal reflection from the walls of the tube. The blackened copper disc for receiving and measuring the radiation is supported near the centre of the tube by means of the fine wires of the thermo-couple. The diameter of the disc is 1·30 cm., and it is set close behind a diaphragm of 14 mm. diameter, so that the whole of its surface is exposed to the radiation. In this arrangement the quantity of radiation measured is determined solely by the diameter of the disc and not by that of the apertures. The disc can be accurately centred and directed on the source of radiation by looking through a small hole at the back of the tube. The cold junctions of the thermo-couples are contained in fine copper tubes soldered to a sliding tube which carries the disc, and is a good fit for the inner tube of the water-jacket. Water at the temperature of the laboratory is continuously pumped by a small motor from one large copper tank to another at a higher level, and flows back continuously and uniformly through the water-jacket of the radio-calorimeter. By this means the temperature of the jacket is maintained very constant without the necessity of making the instrument itself massive or unwieldy.

Observations with different Coatings on the Disc.—With this apparatus it was possible to obtain much more consistent results owing to the greater steadiness of the experimental conditions and the greater ease of adjustment and manipulation. Among other tests, some comparative measurements were made of the relative efficiency of different coatings of black for the disc, of which the following may be taken as samples:—

1. Copper disc clean but not polished. Final excess 1·223° C. $q=\cdot00512$, $r=\cdot00626$, $\mathrm{I}=\cdot00379$.
2. Copper colour just visible through a thin film of smoke-black. Final excess 2·528° C. $q=\cdot00595$, $r=\cdot01505$, $\mathrm{I}=\cdot00910$.
3. Copper disc covered with thick opaque film of smoke-black. Final excess 2·373° C. $q=\cdot006354$, $r=\cdot01508$, $\mathrm{I}=\cdot00912$.
4. Copper disc covered with dead-black varnish of shellac and smoke-black. Final excess 2·159° C. $q=\cdot00703$, $r=\cdot001517$, $\mathrm{I}=\cdot00918$.
5. Same disc, but with new thermo-couple, thick smoke-film. Final excess 2·328° C. $q=\cdot00642$, $r=\cdot01494$, $\mathrm{I}=\cdot00904$.
6. Same disc and couple, but thin black varnish; back also covered. Final excess 1·831° C. $q=\cdot00812$, $r=\cdot01487$, $\mathrm{I}=\cdot00900$.

It will be observed in the above results that the final excess temperature (r/q) and the coefficient of cooling, q, vary considerably under different conditions, but that the results for the rate of heating, r, and the intensity of radiation, q, agree fairly well for the different coatings of black. The same focus-lamp was used as a source in each case, at the same distance, and it is probable that the actual variations in the intensity of the radiation did not exceed one part in 500. The voltage on the

lamp was kept within less than a tenth of a volt of 75·0 volts by the automatic recording potentiometer, and the observations were taken within a few days of each other. In case 1, with the clean metal surface, the value of the coefficient of cooling $q = \cdot 00512$ is nearly that due to convection and conduction alone, as the radiative power of clean metal is very small at these low temperatures, although the absorptive power for the lamp radiation is nearly 40 per cent. An extremely thin coating of smoke-black (2) suffices to raise the absorptive power for the lamp radiation nearly to its maximum, although the radiative power for rays of great wave length is still very low, as shown by the small value of $q = \cdot 00595$, and the high value of the final excess of temperature $r/q = 2\cdot 528°$ C. The thicker coating of smoke-black (3) lowers the value of the final excess to 2·373° C., because the coefficient of cooling is increased in a much greater ratio than the absorptive power for the lamp radiation. It appears from the great increase of q, in case (4), that the dead-black varnish is a much more efficient radiator at low temperatures than the smoke-black, although the absorptive power for the lamp radiation is but slightly increased. The back of the disc was not covered in these experiments in order to obtain a greater rise of temperature. In case (5), with a new thermo-couple, the diminution in the values of r and I, as compared with case (3), may be due simply to unavoidable errors of observation, or slight variations in the uniformity of the wires, or in the quality of the smoke-film ; but it may also be caused by a variation in the cooling of the junctions by conduction, due to slight differences in the attachment of the wires to the disc. In any case it is satisfactory to find that so large a change in the conditions produces a change of less than one per cent. in the result. Similarly, in case (6), the effect of blacking the back of the disc is to produce a very marked increase in the coefficient of cooling ; but although the rate of cooling by radiation is nearly twice as great as in case (5)—supposing that the conduction and convection effects remain the same as in case (1)—the diminution in the result for I, as compared with (4), is not greater than might reasonably be attributed to the thinness of the varnish, which possessed appreciable reflecting power.

It is clear from the above summary that the method is capable of giving fairly consistent results in spite of wide variations in the experimental conditions. But it is evidently necessary to investigate further the absorptive powers of different coatings for radiations of different qualities if it is desired to obtain an order of accuracy higher than one per cent. in the absolute results. Another correction of some importance is that for the cooling of the junction by conduction along the wires. This correction depends on the size of the wires and on their mode of attachment to the disc. Although enormously reduced by the adoption of very fine wires for the couple, it remains distinctly appreciable and requires further investigation. It is evidently possible to determine this correction by employing wires of different sizes simultaneously, or the whole correction may be included in the coefficient of cooling by a suitable arrangement of the junction.

Measurement of Solar Radiation.—Owing to the great intensity and incessant variations of solar radiation, it would not be possible to obtain absolute measurements directly by exposure of the instrument above described to direct sunshine, although such a course has been attempted with instruments of the class of Pouillet's pyrheliometer. Even with the

water-jacket, the conditions of cooling are disturbed by the excessive intensity of the radiation, and the final excess of temperature is much too large to permit of the application of the elementary theory of the method. For these and other reasons it appeared preferable to employ the automatic recording instruments already described[1] for direct exposure to sunshine, and to calibrate the receivers in absolute measure by exposure to the radiation of the focus-lamps, which could be satisfactorily determined by the absolute method.

Bolometric Sunshine Receivers.—These instruments are intended for recording on an arbitrary scale the vertical component of the radiation from the whole sky as well as the sun. This vertical component measures the heat received by the soil, and is probably the factor which chiefly influences the meteorological conditions at any part of the earth's surface, so far as they depend on radiation. It is comparatively useless for this purpose to record merely the normal intensity of solar radiation, as the heat actually received by the earth's surface depends so greatly on the altitude of the sun and the state of the sky. It is proved by actual experiment with these receivers, although it is by no means obvious *à priori*, and will perhaps scarcely be credited at the first statement, that the heat received by reflection from the sky under certain conditions may amount to more than 40 per cent. of the whole vertical component. This being the case, the readings of an instrument which records only the normal intensity of direct sunshine, excluding the radiation from the sky, might give a very incorrect account of the total quantity of heat received by the soil. The form of bolometric receiver adapted for recording the vertical component consists of a differential pair of *flat* platinum thermometers, one blackened and the other bright, placed side by side in the same horizontal plane. The difference of temperature between the two, which is automatically recorded, is approximately a measure of the intensity of the vertical component of the radiation to which they are exposed. It would of course be possible, by providing the instrument with a water-jacketed tube and an equatorial mounting, to make it record the normal intensity of direct sunshine, excluding the greater part of the radiation from the sky; but this would complicate the apparatus considerably, and it is doubtful whether the record would have so direct a bearing on meteorology. It is also certain that the coefficient of cooling by convection would vary at different angles of inclination, whereas it appears to be very constant in the horizontal position.

Two of the bolometric receivers above described have already been compared with the radio-calorimeter by means of the focus-lamps. They were of slightly different patterns, and wound with wire of different sizes, six mils and four mils respectively, but they showed nearly the same difference of temperature when exposed to the same radiation at the same distance. This seems to show that the indications of such instruments are fairly comparable, even if they are not precisely alike. As we have already seen, the absorptive powers of different kinds of black do not appear to differ very much for this kind of radiation. The proportionality of the difference of temperature to the intensity of radiation was also tested by varying the distance from the lamp, and assuming that the radiation followed the law of the inverse square. This is very approximately true for the focus-lamps, owing to the flatness of the radiating

[1] *B.A. Report*, 1898.

grid, provided that the distance is not too small. It is intended in the course of the ensuing year to continue the absolute measurements, and to test the performance of the automatic recorders under a greater variety of conditions, for which Mr. Wilson, of Daramona Observatory, has promised his assistance; but enough has already been accomplished to show that the apparatus affords a very promising and practical method of recording and reducing to absolute measure the vertical intensity of radiation at any point of the earth's surface.

Uniformity of Size of Pages of Transactions.—Report of the Committee, consisting of Professor S. P. THOMPSON (*Chairman*), Mr. J. SWINBURNE (*Secretary*), Professor G. H. BRYAN, Mr. C. V. BURTON, Mr. R. T. GLAZEBROOK, Professor A. W. RÜCKER, *and* Dr. G. JOHNSTONE STONEY, *appointed to confer with British and Foreign Societies, publishing Mathematical and Physical Papers, as to the Desirability of securing Uniformity in the Size of the Pages of their Transactions and Proceedings.* (*Drawn up by* J. SWINBURNE.)

A LARGE number of journals were measured to find what dimensions it would be best to choose as standards. An account of this work was published in the Report for 1895, p. 77.

Since that date a large volume of correspondence has been carried on with the English and foreign scientific societies.

In most cases the societies' publications come within the limits specified in the first report.

In some of the cases the societies agreed to alter their publications so as to come within the standard limits.

In a few cases the societies prefer to continue the use of abnormal dimensions rather than alter their publications, especially when the publication has been going on for many years.

The importance of beginning a paper on the right-hand page is generally realised, but there are difficulties in carrying it out. In spite of this, a few of the societies are endeavouring to arrange that all important papers shall begin on the right-hand page.

The Committee do not ask for reappointment.

Determining Magnetic Force on Board Ship.—Report of the Committee, consisting of Professor A. W. RÜCKER (*Chairman*), Dr. C. H. LEES (*Secretary*), Lord KELVIN, Professor A. SCHUSTER, Captain CREAK, Professor W. STROUD, Mr. C. VERNON BOYS, and Mr. W. WATSON, *appointed to consider the most suitable Method of determining the Components of the Magnetic Force on Board Ship.*

AN instrument which embodies the ideas of Captain Creak, mentioned in last year's Report, has been constructed. Although specially designed for observations on board ship, it will probably from its strength of construction be found suitable for travelling parties.

The Committee apply for reappointment, with the unexpended grant of 10*l*. made last year.

Tables of certain Mathematical Functions.—Report of the Committee consisting of Lord KELVIN (*Chairman*), Lieutenant-Colonel ALLAN CUNNINGHAM, *R.E.* (*Secretary*), Dr. J. W. L. GLAISHER, Professor A. G. GREENHILL, Professor W. M. HICKS, Professor A. LODGE, and Major P. A. MACMAHON, *R.A.*, *appointed for calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the calculations, and to publish the results in an accessible form.*

THE cost of printing the Tables (Binary Canon) was estimated at 135*l.* A grant of 75*l.* only was made at the Dover Meeting. As the Tables could not have been printed for this sum, application was made to the Royal Society for a grant in aid, and the Royal Society has granted the remaining sum (60*l.*) required. The Tables have been put in hand, and are now (September) nearly all in type: they should be finished before next Meeting.

Meteorological Observations of Ben Nevis.—Report of the Committee, consisting of Lord M'LAREN, Professor A. CRUM BROWN (*Secretary*), Sir JOHN MURRAY, Professor COPELAND, *and* Dr. ALEXANDER BUCHAN. (*Drawn up by* Dr. BUCHAN.)

THE Committee was appointed as in past years for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations at the two Ben Nevis Observatories.

The hourly eye observations made by night as well as by day, which are a specialty of the High Level Observatory, have been made with complete regularity throughout the year by Mr. Rankin and his assistants.

The health of the staff at the High Level Observatory continued good, and the laborious work of the observations has been carried on without the loss of an hour's observations. The Directors desire to express their hearty thanks to Messrs. T. Affleck, George Ednie, M.A., J. S. Begg, M.A., G. A. S. Tait, R. C. Marshall, and T. Kilgour for the invaluable service they rendered as volunteer observers during the summer of 1899, thus affording to the members of the staff the relief and rest they so much needed. Owing to the war in South Africa some changes took place in the Observatory staff. In October J. Bell, reservist, was called out for service, and subsequently R. M. McDougall and D. Grant left to join the forces. At the Low Level Observatory at Fort William influenza of an acute form for a second time prevailed. But it is gratifying to add that no observations have been lost, and the arrears of copying and computations which necessarily occurred are being gradually worked off.

The observations at the intermediate station at Ben Nevis were undertaken, single-handed, by Mr. D. W. Wilton. These valuable observations, together with the similar observations made at this station during the previous three summers, are being discussed under the superintendence of Mr. Omond.

The principal results of the observations of 1899 are detailed in Table I.

TABLE I.

1899	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Pressure in Inches.													
Ben Nevis Observatory	25·048	25·149	25·317	25·146	25·431	25·559	25·528	25·598	25·209	25·379	25·321	25·163	25·321
Fort William	29·640	29·738	29·944	29·730	30·008	30·043	30·012	30·053	29·707	29·923	29·875	29·775	29·871
Differences .	4·592	4·589	4·627	4·584	4·577	4·484	4·484	4·455	4·498	4·544	4·554	5·612	4·550
Mean Temperatures.													
Ben Nevis Observatory	23°·7	26°·5	25°·3	26°·4	32°·0	43°·7	43°·1	48°·7	35°·4	33°·7	32°·3	23°·7	32°·9
Fort William	37·6	39·0	40·3	43·0	47·7	57·4	58·4	60·6	52·2	48·7	48·3	38·1	47·6
Differences .	13·9	12·5	15·0	16·6	15·7	13·7	15·3	11·9	16·8	15·0	16·0	14·4	14·7
Extremes of Temperature, Maxima.													
Ben Nevis Observatory	35·1	39·2	46·0	41·3	47·0	60·6	57·4	63·5	50·6	48·2	43·9	40·0	63·5
Fort William	52·0	50·0	54·4	62·0	66·0	76·2	71·1	80·3	65·4	61·5	62·3	53·3	80·3
Differences .	16·9	10·8	8·4	20·7	19·0	15·6	13·7	16·8	14·8	13·3	18·4	13·3	16·8
Extremes of Temperature, Minima.													
Ben Nevis Observatory	12·2	10·6	6·9	13·1	20·0	30·3	33·6	33·1	23·3	19·9	21·0	10·8	6·9
Fort William	23·1	24·5	21·0	26·4	32·2	43·7	47·7	45·2	34·0	32·6	32·2	17·4	17·4
Differences .	10·9	13·9	14·1	13·3	12·2	13·4	14·1	12·1	10·7	12·7	11·2	6·6	10·5
Rainfall, in Inches.													
Ben Nevis Observatory	15·30	10·56	25·21	17·01	6·88	7·61	15·23	5·58	20·78	18·11	32·48	12·55	187·30
Fort William	7·38	4·91	8·65	5·37	2·56	2·05	4·45	1·77	9·11	9·10	13·27	5·96	74·58
Differences .	7·92	5·65	16·56	11·64	4·32	5·56	10·78	3·81	11·67	9·01	19·4	6·59	112·72
Rainfall, Greatest Daily Fall.													
Ben Nevis Observatory	1·82	1·89	3·34	3·97	1·87	1·19	3·21	1·21	2·26	3·78	4·33	2·98	4·33
Fort William	1·74	0·86	1·36	0·76	0·48	0·56	1·26	0·54	1·50	1·48	1·68	0·92	1·74
Differences .	0·08	1·03	1·98	3·21	1·39	0·63	1·95	0·67	0·76	2·30	2·65	2·06	2·59
Number of Days 1 in. or more fell.													
Ben Nevis Observatory	7	3	11	4	2	3	5	1	7	6	13	4	66
Fort William	1	0	2	0	0	0	1	0	1	4	3	0	12
Differences .	6	3	9	4	2	3	4	1	6	2	10	4	54
Number of Days 0·01 in. or more fell.													
Ben Nevis Observatory	22	11	27	26	14	20	23	12	28	22	26	22	253
Fort William	21	13	22	20	11	14	19	12	26	20	26	19	223
Differences .	1	2	5	6	3	6	4	0	2	2	0	3	30
Mean Rainband (scale 0–8).													
Ben Nevis Observatory	1·8	1·5	2·0	2·2	2·3	2·2	3·0	2·0	2·2	2·9	2·7	1·7	2·2
Fort William	3·1	2·9	3·3	3·6	3·5	3·9	3·9	4·1	4·0	4·1	4·8	3·2	3·7
Differences .	1·3	1·4	1·3	1·4	1·2	1·7	0·9	2·1	1·8	1·2	2·1	1·5	1·5
Number of Hours of Bright Sunshine.													
Ben Nevis Observatory	33	79	52	56	164	153	60	212	12	52	12	12	897
Fort William	26	71	83	112	197	168	89	231	73	69	12	8	1,139
Differences .	7	8	31	56	33	15	29	19	61	17	0	4	242
Mean Hourly Velocity of Wind, in Miles.													
Ben Nevis Observatory	19	20	13	17	10	11	10	10	12	18	19	16	15
Mean Percentage of Cloud.													
Ben Nevis Observatory	85	68	86	88	71	73	92	60	96	86	95	88	82
Fort William	75	63	79	74	68	70	86	54	80	73	87	81	74
Differences .	10	5	7	14	3	3	6	6	16	13	8	7	8

This table shows for 1899 the mean monthly and extreme pressure and temperature, amounts of rainfall with the number of days of rain and the days on which the amount equalled or exceeded one inch ; the hours of sunshine, the mean percentage of cloud, the mean velocity of the wind in miles per hour at the top of the mountain, and the mean rainband at both observatories. The mean barometric pressures at Fort William are reduced to 32° and sea level, but those at the Ben Nevis Observatory only to 32°.

At Fort William the mean atmospheric pressure for the year was 29·871 inches, being 0·027 inch greater than the mean of the forty years ending 1895. The mean at the top was 25·321 inches, being 0·025 inch above the average of the observation since the opening of the Observatory in 1883. The difference for the two observatories was thus 4·550 inches, being all but identical with the difference of previous years. At the top of the mountain the absolutely highest pressure for the year was 26·058 inches, and at Fort William 30·728 inches, both readings occurring on November 17.

The differences from the mean monthly barometric pressure much exceeded the averages in June, July, and August, the excess for the three months for Fort William being 0·172 inch, and for Ben Nevis 0·160 inch. On the other hand, for January and April the deficiencies from the averages were 0·164 inch and 0·160 inch for Fort William, and for Ben Nevis 0·164 inch and 0·165. In the summer months, when pressure was abnormally high, the type of weather was anticyclonic, but in January and April, when pressure was unusually low, the type of weather was cyclonic.

The deviations of the mean temperature of the months from their respective averages are shown in Table II. :—

TABLE II.

	Fort William.	Top of Ben Nevis.		Fort William.	Top of Ben Nevis.
	°	°		°	°
January	−1·0	−0·1	July	1·8	2·4
February	0·2	2·6	August	4·7	8·2
March	−0·2	1·5	September	−0·8	−2·4
April	−1·9	−1·1	October	1·7	2·0
May	−2·3	−1·0	November	5·0	3·7
June	2·2	4·4	December	−2·5	−1·4

The highest monthly mean temperature hitherto yet observed on Ben Nevis was 48°·7 for August, which was 8°·2 above the mean of previous Augusts. The excess of mean temperature of the three summer months was 5°·0 above the average, whereas at Fort William the mean excess was only 2°·9. In the strongly marked type of anticyclonic weather which then prevailed, the temperature at the top of Ben Nevis was relatively very much higher than at Fort William. Hence, while the normal difference of temperature in August at the top and bottom of the hill is 16°·4, in August 1899 it was only 11°·9. The absolutely highest temperature for the year at Fort William was 82°·0 on August 24 ; and at the top of Ben Nevis 63°·5 on August 23. The absolutely lowest was 15°·2 at Fort William on December 28 ; and on Ben Nevis 6°·9 on March 23.

In Table III. are given for each month the lowest observed hygrometric readings at the top of Ben Nevis :—

TABLE III.

—	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	°	°	°	°	°	°	°	°	°	°	°	°
Dry Bulb . .	26·4	28·0	43·5	19·2	41·0	52·6	47·5	51·4	40·3	43·6	27·0	12·2
Wet Bulb . .	18 7	20·4	29·8	15·9	28·9	38·4	37·0	37·0	31·2	32·2	22·0	9·7
Dew-point . .	−22·9	−10·8	13·4	−8·1	13·2	24·1	25·4	21·2	19·4	18·5	−1·0	−9·8
Elastic Force .	·014	·025	·079	·029	·078	·130	13·7	·114	·105	·100	·042	·026
Relative Humidity (Sat.=100)	10	16	28	28	30	33	42	30	42	35	28	35
Day of Month .	27	19	16	21	11	15	30	1	10	21	15	14
Hour of Day . .	8 A.M.	5 P.M.	5 P.M.	4 A.M.	10 P.M.	9 P.M.	2 A.M.	9 P.M.	8 P.M.	7 P.M.	2 A.M.	4 P.M.

Of these relative humidities, the lowest 10 occurred on January 27 with a dew-point of —22°·9, and the highest 42 on July 30 with a dew-point of 25°·4. It is to be noted that with these humidities the accompanying dew-point fell in five of the months below zero, thus being in striking contrast with the lowest monthly humidities of the previous year, when the lowest was only 23, and the dew-point fell below zero only in December.

The sunshine recorder on Ben Nevis showed 897 hours out of a possible 4,470 hours, being 132 hours more than in 1898, or 20 per cent. of the possible sunshine. This far exceeded the average of past years, which is only 750 hours, being only exceeded in 1888, when the number of hours was 970. The minimum occurred in 1884, when only 510 hours were registered by the sunshine recorder. At Fort William the number of hours was 1,139, being 102 hours fewer than in 1898. At both observatories the monthly maximum was in August, being 231 hours at Fort William and 212 hours at the top of Ben Nevis, amounts nearly d uble the average of any previous August. This unwonted amount of sunshine was occasioned by the strongly pronounced anticyclonic character of the weather of August 1899. In the following month, September, only 12 hours were recorded at the Ben Nevis Observatory, or less than 1 per cent. of the possible sunshine. In no previous summer month has the recorded sunshine been so decidedly deficient.

At the Ben Nevis Observatory the mean percentage of cloud was 82, or a little under the average, the highest being 96 in September, and the lowest 60 in August. At Fort William the mean was 74, the highest being 87 in November, and the lowest 54 in August, or little more than a sky half covered with cloud.

The mean rainband observation (scale 0–8) was 2·2 at the top for the year, the maximum being 3·0 in July, and the minimum 1·5 in February. The annual mean at Fort William was 3·7, the maximum being 4·8 in November, and the minimum 2·9 in February.

The mean hourly velocity of the wind at the top of the mountain was at the rate of 15 miles per hour, the maximum monthly velocity being 20 miles in February and the minimum 10 miles in May, July, and August

The rainfall for the year at the Ben Nevis Observatory was 187·30 inches, being 31·82 inches, or 22 per cent. above the average. This large annual rainfall has been only twice exceeded, viz. in 1898 and 1890, when it was respectively 240·05 inches and 197·95 inches. It is noteworthy that while the rainfall at the top of Ben Nevis was 22 per cent above

the average, at the neighbouring surrounding stations near sea level the rainfall was about 10 per cent. under the average. It will be observed that the large excess on Ben Nevis was almost wholly occasioned by the extraordinarily heavy rainfall there in November and March. In these months there prevailed over Scotland an unusual excess of south-westerly winds. The largest monthly rainfall, 32·48 inch, occurred in November, when south-westerly winds prevailed eight days more than the average, and the mean temperature of the month over Scotland was 46°·4, or 5°·8 above the average of the month, an excess of south-westerly winds and of mean temperature hitherto unparalleled for November. The heaviest rainfall on any single day was 4·68 inches in December. At Fort William the annual rainfall was 74·58 inches, and the largest monthly amount was 13·27 inches in November, when the rain-bringing south-westerly winds were so prevalent. The heaviest fall on any single day was 1·63 inch in March.

At the top of Ben Nevis rain fell on 253 days, and at Fort William on 223 days. At the top the monthly maximum was 28 days in September, and the minimum 11 days in February, and at Fort William the maximum was 26 days in September, and the minimum 12 in August.

During the year the number of days on which 1 inch of rain or more fell was 66 at the top and 12 at Fort William, the former being 18 above the average and the latter 5 below it.

Auroras were observed on the following dates :—February 12 ; March 10, 16, 21, 22 ; May 2, 3, 4, 5, 6 ; and October 15.

St. Elmo's Fire was seen on January 6, 13, 15 ; March 28 ; August 25 ; September 19, 20, 23 ; October 30 ; and November 6, 8, 10, 11.

Zodiacal Light :—On October 15.

Thunderstorms :—On August 25 ; September 17, 18 ; and October 13, 30.

Lightning only :—On January 16 ; February 12 ; and September 29.

Solar Halos :—January 2 ; March 30 ; April 9, 12, 18, 19, 20, 22 ; May 9, 12, 22, 31 ; June 10, 17 ; July 6 ; and August 5, 18.

Lunar Halos :—January 17, 26, 27, 28 ; February 18, 21, 22 ; March 24 ; April 19, 20 ; June 27 ; October 21, 22 ; November 9 ; and December 10, 12, 13, 23.

Much time has been taken up in revising the proof-sheets of the hourly observations of the Ben Nevis Observatories now in the press, and the work of printing is proceeding at a fairly satisfactory rate. It need scarcely be added that the revision of the work, which will fill three large quarto volumes, is peculiarly heavy. The work of reduction and entering on daily sheets the hourly observations of the two observatories is practically brought down to date. The daily maps of rainfall, fog, storms, and other weather phenomena are also completed to date ; and for several selected months there are already entered on the same maps the details for storms, forecasts, and storm warnings. With these are compared the hourly observations at the two observatories with the view of arriving at some definite knowledge of the relations existing among the phenomena observed. Particular attention is given in the first place to the relations between the double set of observations made at Ben Nevis and the forecasts and warnings issued from the Meteorological Office in London of storms, rain, fog, and other weather phenomena.

For several months Mr. Omond had under discussion all hourly temperatures observed at Fort William and the top of the mountain, showing

a difference between the two temperatures distinctly less than the usual difference, together with all cases where the temperature at the top exceeded that at Fort William at the time. It will be readily recognised that this work is largely an inquiry into the anticyclone, and its connections with the cyclone and weather changes which accompany their changing relations.

Dr. Buchan's time has been largely occupied with the discussion of the fogs observed at the Scottish lighthouses night and day from 1889 to 1899. These data, as stated, are all entered on two daily maps, to each of which are attached the weather maps of the Meteorological Office for the day in question as issued in the weekly maps of the office, in addition to which the daily direction and force of the wind at eleven selected lighthouses are given. Thus the general character of each day's weather is readily seen, and the direction of the wind at the time the fogs were recorded. The fogs here examined are not land fogs, but sea fogs, a correct knowledge of which is of paramount importance to navigation.

The more important results arrived at are these :—The annual maximum period is from April to June, and the minimum from October to February, being thus generally the reverse of land fogs. The worst and longest continued fogs occur with easterly winds, and their occurrence is restricted to the east coast of Scotland. On the other hand, the fogs on the west coast accompany westerly winds. These are much more frequent and prolonged at places directly open to the Atlantic than at places such as Rothesay, Oban, and Stornoway, which are sheltered from the Atlantic by land of a greater or less extent and height.

Conjoined with this discussion is the excessively heavy rain brought by the easterly winds on the east coast of Scotland, and to a greater or less extent inland according to the height to which these rain-bringing easterly winds extend in the atmosphere. On this point the conjoined observations of the two Ben Nevis Observatories contribute invaluable knowledge.

An examination of daily weather maps of Europe constructed from the daily weather maps of the British Islands, France, and Germany makes it clear that these heavy rains and easterly winds occur when barometric pressure diminishes from the Baltic and westwards through the North Sea to the West of Scotland. It is here particularly to be noted that at the same time humidities are high over those parts of the Continent whence these easterly winds have come prior to their arrival in Scotland. Of these rain storms the great rains in the east of Scotland on April 27 to 30, 1898, and on August 22, 1900, are among the most remarkable; they are therefore being investigated in great fulness of detail.

It will be known, from your Committee's previous reports, that gales and storms of wind have for many years been observed night and day at the Scottish lighthouses with a fulness and an accuracy attempted nowhere else. Much time has been given to the discussion of these observations in their relations to the other weather phenomena charted on the daily weather maps. One of the results already arrived at—and it is an important one—is that the first step to be taken in any investigation of storms is the partition of Scotland into eight or ten divisions based on the physical features of the country in their relations to the more prominent storm-bringing winds. The inquiry is therefore proceeding on these lines.

If a meteorologist knows the distribution of barometric pressure over Western Europe, he can then at once state what the weather is in each part of the countries for which he has this information, and he can describe the weather in fulness of detail just according to the accuracy and abundance of the barometric readings supplied to him. This valuable practical result is a direct consequence of the scientific study of the relations of barometer, temperature, and wind as observed over the whole world and interpreted in accordance with physical laws.

Now this is not forecasting, but only the description of the weather at the time the barometric readings were taken. But it necessarily follows that if the forecaster can guess what the distribution of barometric pressure will be at some future time, he can state what the weather will be at that time. Hence the whole problem of forecasting resolves itself into foreseeing the arrangement of barometric pressure in the future. The distribution of pressure does not shift arbitrarily, but the areas of high and low pressure existing on any one day change into those of the next by movement over the surface of the earth and by increase or diminution in intensity, in accordance with physical laws.

The scientific study of the causes of the movements of these areas of high and low pressure, called respectively anticyclones and cyclones, can only be said to be just beginning. Until this great inquiry has made some substantial progress we cannot have a science of forecasting, as we now have a science of climatological meteorology.

These areas of low and high pressures are not mere surface phenomena, but extend upwards through the atmosphere, and their movements are largely determined by the conditions surrounding them in the upper regions of the atmosphere.

Towards the expenses of publishing the hourly observations of the two Ben Nevis Observatories the Royal Society of London has made a grant of 500*l.*, and a grant to the same amount has been made by the Royal Society of Edinburgh. These societies thus approve of the publication as a necessary preliminary to the scientific study of forecasting. The Ben Nevis Observatories have already largely contributed to the fundamental data of meteorology, and in the future the observations they supply will take a prominent place in the development of scientific forecasting.

Your Committee have the greatest pleasure in adding that at the meeting of the Scottish Meteorological Society in March last J. Mackay Bernard, Esq., of Dunsinnan, intimated a third handsome donation of 500*l.* towards the maintenance of the observatories to the end of next year. Another gentleman, on learning that assistants were urgently required to assist Dr. Buchan and Mr. Omond in the office, at once readily and most generously intimated a donation of 300*l.* to the Council of the Society for the purpose.

Radiation in a Magnetic Field.—Report of the Committee, consisting of Professor G. F. FitzGerald (*Chairman*), *the late* Professor T. Preston (*Secretary*), Professor A. Schuster, Professor O. J. Lodge, Professor S. P. Thompson, Dr. Gerald Molloy, *and* Dr. W. E. Adeney.

The Committee regret that they are unable to report that any further work has been done with the great spectroscope belonging to the Royal

University of Ireland owing to the illness and death of the Secretary of the Committee, Professor T. Preston, F.R.S. They desire to be re-appointed without a grant for the purpose of publishing copies of Professor Preston's photographs, as they believe that a good deal of useful work could be done upon these photographs by persons who are not possessed of the spectroscopic and magnetic power required to produce the phenomenon on a large scale. Others may desire to obtain copies of the photographs as illustrations of this interesting effect of magnetisation on light.

Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Mr. R. T. GLAZEBROOK (*Secretary*), Lord KELVIN, Professors W. E. AYRTON, J. PERRY, W. G. ADAMS, OLIVER J. LODGE, *and* G. CAREY FOSTER, Dr. A. MUIRHEAD, Sir W. H. PREECE, Professors J. D. EVERETT *and* A. SCHUSTER, Dr. J. A. FLEMING, Professors G. F. FITZGERALD *and* J. J. THOMSON, Mr. W. N. SHAW, Dr. J. T. BOTTOMLEY, Rev. T. C. FITZPATRICK, Professor J. VIRIAMU JONES, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, Mr. J. RENNIE, Mr. E. H. GRIFFITHS, Professor A. W. RÜCKER, Professor H. L. CALLENDAR, Mr. GEORGE MATTHEY, *and* Sir W. ROBERTS-AUSTEN.

DURING the year the resistance coils and other apparatus belonging to the Committee have been removed to Richmond. Most of the apparatus has been set up in an outbuilding attached to the Kew Observatory, which has been fitted by the Committee of the National Physical Laboratory as a temporary laboratory.

It is interesting to note that the case containing the original coils of the Association bears the words, 'To be deposited at Kew.' After many wanderings the coils have at last returned to their home.

The Sub-Committee on Platinum Thermometry held a meeting in the spring, and agreed to the following resolutions :—

(i) That a particular sample of platinum wire be selected, and platinum thermometers be constructed therefrom to serve as standards for the measurement of high temperature.

(ii) That Mr. Glazebrook and Professor Callendar be requested to consider the details of the selection of wires and construction of thermometers for the above purpose, and to consult with Mr. Matthey, who kindly consented to give his assistance.

Since then Mr. Matthey has supplied the Sub-Committee with two specimens of very pure platinum. Portions of these have been made into thermometers and tested at the National Physical Laboratory, with the following results, R_0 being the resistance at 0° and R_{100} at 100°, while δ is the coefficient occurring in Callendar's difference formula :

	R_{100}/R_0	δ
Wire 1	1·3883	1·493
„ 2	1·3884	1·498

The question of the selection of a wire for the construction of the standards is still under the consideration of the Committee.

During the summer a very full comparison has been made of the unit resistance coils of the Association, and the opportunity has been taken of comparing these with some coils belonging to the Board of Trade, and with others which have recently been obtained from the Reichsanstalt. The coils were also compared with one of the mercury resistance tubes prepared by M. Benoit in 1885, and which has been in the care of the Secretary since that date.

The results have not yet been completely worked out, and publication is, therefore, necessarily deferred. Moreover, the temperature during July was very high, so that the mean temperature of the observations is much above that at which previous comparisons have been made. For the purpose, therefore, of connecting these results with the past it will be desirable to make some further observations in the autumn.

It seemed desirable to set up some mercury resistance tubes in England, with a view of keeping a check on the variations of the wire standards.

Preparations have been made for this. A number of selected tubes of 'verre dur' have been obtained, with the kind assistance of the officials of the Bureau International, from M. Baudin, while other tubes of Jena glass have been procured from Schott & Co. Steps are being taken to have some of the best of these calibrated.

Some advance has been made during the year with the construction of the Ampère balance. The Committee greatly regret the serious illness of Prof. J. V. Jones, which has prevented more rapid progress. The stand for raising and lowering the outer coils has been completed. Thanks to the generosity of Sir A. Noble, the cost of this, estimated at about 100*l.*, has been saved the Committee.

During the spring the Secretary, as Director of the National Physical Laboratory, visited the Bureau International at Paris and the Reichsanstalt at Berlin. The Committee are glad to put on record their appreciation of the great courtesy and kindness with which he was received by President Kohlrausch, M. Benoit, and the other officials connected with those institutions.

The Committee are informed that at the recent International Electrical Congress at Paris the two following resolutions were unanimously adopted by Section I, and confirmed by the Congress and by the Chamber of Government Delegates :—

1. The Section recommends the adoption of the name of Gauss for the C.G.S. unit of magnetic field.

2. The Section recommends the adoption of the name of Maxwell for the C.G.S. unit of magnetic flux.

The question of giving names to the units of magnetic force and flux has been before the Committee on several occasions. The Committee therefore were in a position to welcome cordially these resolutions, and at their last meeting agreed unanimously to a resolution adopting the two names selected by the Paris Congress.

Of the sum of 25*l.* voted last year, 13*l.* 7*s.* 7*d.* has been expended on material for the new platinum thermometers and on the transport of the apparatus from Liverpool to Richmond. If the plan of constructing standards for platinum thermometers is adopted, it will be necessary to purchase a large stock of suitable wire, the whole of which should be made at the same time. For this a considerable expenditure will be required ; there

will also be incidental expenses connected with the making and standardising of the thermometers. For these purposes the Committee ask for a grant of 75*l.*

The Committee therefore recommend that they be reappointed, with a grant of 75*l.*, and that Lord Rayleigh be Chairman and Mr. R. T. Glazebrook Secretary.

APPENDIX.

Note on an Improved Standard Resistance Coil. *By* Robert S. Whipple.

The coil in question consists of a bare wire wound on a mica frame.

This form of coil possesses the following advantage over the ordinary resistance coil :—(1) The coils can be annealed to a dull red heat *in situ*, thus relieving the wire of any strain caused by the winding. (2) The heating of a wire immersed in oil is less than one silk-covered and varnished. (3) The temperature of the wire can be accurately determined by means of a thermometer placed in the oil surrounding the wire. German physicists have adopted a form of coil in which the wire is silk-covered and varnished and then placed in a metal case perforated with holes. The whole coil is placed in an oil bath when in use. This form of coil is open to the objection that it cannot be annealed above 140° C. without causing injury to the silk covering on the wire, and there is a certain amount of lag in the oil obtaining the temperature of the coil.

By request of the Electrical Standards Department of the Board of Trade the Scientific Instrument Co., Cambridge, have designed and made two standard 1-ohm coils the wires of which are bare and immersed in oil; a modification suggested by Mr. Horace Darwin was also fitted for obtaining the temperature of the coils. The coils proper consist of 0·035 in. PtAg wire wound on mica frames, the ends of the wires being attached to stout copper terminals in the usual manner. A 0·08 in. platinum wire is wound alternately with the platinum-silver wire, and is attached similarly to stout copper leads. Both coils are adjusted to a resistance of 1 ohm at 15°·5 C. Owing to the difference in the temperature coefficient of the two wires (PtAg 0·00024, Pt 0·00350), a small change in the temperature of the coil causes a comparatively large difference between the resistances of the two coils. This difference being known, the temperatures in degrees Centigrade is given by the adjoined table. The table is calculated from the difference in the temperature coefficients of the two wires 0·00350−0·00024=0·00326 for 1° C.

Temperature of standard coil	Difference in resistance of the coils	
10°·0 C.	−0·01793	Platinum coil having a lower resistance than the platinum-silver coil.
11°·0 C.	0·01467	
11°·9 C.	0·01141	
13°·0 C.	0·00815	
14°·0 C.	0·00489	
15°·0 C.	−0·00163	
15°·5 C.	0·00000	
16°·0 C.	+0·00163	Platinum coil having a higher resistance than the platinum-silver coil.
17°·0 C.	0·00489	
18°·0 C.	0·00815	
19°·0 C.	0·01141	
20°·0 C.	+0·01467	

As the temperature coefficient of platinum is about fifteen times as great as that of platinum-silver, the resistance of this coil may be measured to one significant figure less than the standard coil without affecting the value for the temperature of this coil. In measuring small resistances the determination of the last figure to 0·00001 ohm requires considerable care, and the advantage of not being compelled to measure to such a high degree of accuracy is apparent. The two wires being wound on the same frame alternately with each other and immersed in oil are at the same mean temperature. Any temperature gradient in the oil influences both wires similarly, thus doing away with the necessity of a stirrer. The platinum wire is also useful for testing the insulation of the windings of the PtAg coil one from the other. The coils are placed in a glass vessel in order that the behaviour of the insulating oil with time may be studied.

Photographic Meteorology.—Tenth Report of the Committee, consisting of Professor R. MELDOLA, Mr. A. W. CLAYDEN (*Secretary*), Mr. J. HOPKINSON, *and* Mr. H. N. DICKSON. (*Drawn up by the Secretary.*)

THE Committee have suffered a severe loss during the past year by the death of the Chairman, Mr. G. J. Symons, F.R.S., whose genial presence and energetic support will be greatly missed from many scientific societies, and especially from those which are interested in meteorology. This is not the place to attempt any adequate eulogium of his life's work, which, indeed, is too well known to need description.

The observational work in progress was brought to an abrupt end early in October. On visiting the ground where the cameras stood in order to make some measurements it was found that the connecting wire between the two stations had been blown down by a heavy gale a few days before. The poles were snapped in two, several of the insulators broken, and the connections to the cameras damaged.

It was felt that it was not worth while to re-erect the line on the same site, as the number of observations already made was rather more than 400, and also because the site had become much less convenient.

It was on some waste ground belonging to the L. & S. W. R. Co., near their engine sheds. At first this was very little disturbed, but for the last two years railway operations have been encroaching on the space, a preliminary process being the deposit of great quantities of rubbish.

Attempts were made to find another suitable site, but none seemed available within a convenient distance, and the expense of re-erecting the line and repairing the apparatus would be considerable and not worth incurring unless frequent observations were possible.

It seemed, therefore, that the best course would be to summarise the results so far attained and suspend measurements until a favourable opportunity should occur.

So far the total number of measurements made is 423. These include no measurements of the variety of cloud known as nimbus and very few of true stratus, the great majority being of cirrus, cirro-stratus, cirro-cumulus, alto-cumulus, and alto-stratus.

The following tables show a comparison between the Exeter measurements and those made at Blue Hill and Upsala respectively :—

Maximum Altitudes in Metres.

—	Blue Hill	Upsala	Exeter	No. of Observations
Cirrus	14,930	13,376	27,413	58
Cirro-stratus	12,134	11,391	15,503	64
Cirro-cumulus	10,520	10,235	11,679	63
Alto-cumulus	8,204	8,297	9,390	83
Cumulus top	—	3,611	4,582	42
Cumulus base	3,582	2,143	1,959	48
Strato-cumulus	3,328	4,324	6,926	27
Cumulo-nimbus top	—	5,970	6,409	15
Cumulo-nimbus base	1,590	1,630	2,286	15

Minimum Altitudes in Metres.

—	Blue Hill	Upsala	Exeter
Cirrus	5,392	4,970	4,114
Cirro-stratus	2,290	4,740	3,840
Cirro-cumulus	4,772	3,880	3,657
Alto-cumulus	784	1,498	1,828
Cumulus top	1,455	900	—
Cumulus base	601	743	584
Strato-cumulus	1,109	887	823
Cumulo-nimbus top	—	1,400	2,004
Cumulo-nimbus base	884	1,180	766

Mean Altitudes in Metres.

—	Blue Hill	Upsala	Exeter
Cirrus	9,923	8,878	10,230
Cirro-stratus	7,617	7,226	9,540
Cirro-cumulus	7,606	6,465	8,624
Alto-cumulus	4,787	4,178	5,348
Cumulus top	2,181	1,855	3,006
Cumulus base	1,473	1,386	1,290
Strato-cumulus	2,003	2,331	2,248
Cumulo-nimbus top	—	2,848	8,002
Cumulo-nimbus base	1,202	1,405	1,045

In making such a comparison there are many difficulties, for the different types of cloud so merge into each other that unless the figures are known to relate positively to clouds resembling a certain type picture any agreement can only be general.

It will be seen that the maximum values at Exeter exceed those of the American and Swedish observations in every case except that of the base of cumulus. It should be noted, however, that several of these maxima occurred on one day (June 12, 1896). If that one day had been omitted, the maxima for cirrus and cirro-stratus would be only about 1,000 metres greater than the Blue Hill values.

In comparing the mean values a similar remark holds good, the greater values at Exeter being due to a small number of extreme observations.

The minimum altitudes recorded at Exeter compare fairly well with the others, some of the differences being most probably due to nomenclature.

Several series of observations have been made in a single day with the object of determining the rise or fall of clouds. It is clear from these that on an average day the cloud planes rise steadily until the early afternoon, between 2 and 3 p.m., when the maximum for the day is usually reached. This is followed by a fall, which gets more and more rapid towards sunset. In calm weather, or weather with only a moderate breeze and no great barometric disturbance, this diurnal rise and fall is very clearly marked; but in broken weather, with strong winds, showers, or barometric changes, it may be completely masked.

Cumulus is the result of an upward movement, but cirro-cumulus and alto-cumulus may sometimes be the result of a descending movement, in which case the lumpy form is never persistent, but passes into a stratiform cloud very quickly.

True cirrus of the whispy form is described by some meteorologists as due to a rapid ascending current, by others to an equally rapid descent. The measurements made indicate that this form of cloud may exist with an upward or a downward movement, or with no recognisable movement at all.

The greatest altitudes have been found with thunderstorm conditions, the lowest (excepting fog) with cyclonic.

The measurements compared in the foregoing tables have all been made between April and October inclusive. In the winter months the ground has generally been too wet for use, and the figures from the foreign stations are for the summer months only. It seems difficult at first to see why the altitudes should, on the whole, be greater at Exeter, the greater humidity of the air leading rather to the expectation of more easy cloud production, and therefore lower altitudes. But the fact of thunderstorm conditions being attended, as they seem always to be attended, by great cloud altitudes suggests another explanation. This is that vapour in a cloud-producing quantity exists to a greater height above Devonshire. It will be noticed that the greater altitudes are true only of the higher clouds, and that the mean level of the base plane of cumulus and cumulo-nimbus is actually lower at Exeter than at either of the other stations.

The photographs collected some years ago by the Committee have been placed in the care of the Royal Meteorological Society, with the exception of prints from the negatives belonging to the Secretary, who will add them as opportunity offers.

During the past year the Secretary has made a number of experiments with the Ives and Joly processes for photography in natural colours, but has found that, although either process can be made to record the colour of a cloud, the tints of a sunset, or even the colours of the rainbow, the reproduction of the colours is so far from being an automatic process that neither method promises to be of very great meteorological value except in the hands of experts.

Seismological Investigations.—Fifth Report of the Committee, consisting of Professor J. W. JUDD (*Chairman*), Mr. JOHN MILNE (*Secretary*), Lord KELVIN, Professor W. G. ADAMS, Professor T. G. BONNEY, Sir F. J. BRAMWELL, Mr. C. V. BOYS, Professor G. H. DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Professor J. H. EWING, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Mr. W. E. PLUMMER, Professor J. H. POYNTING, Mr. CLEMENT REID, Mr. NELSON RICHARDSON, the late Mr. G. J. SYMONS, *and* Professor H. H. TURNER.

[PLATES II. AND III.]

CONTENTS.

I. *On Seismological Stations abroad and in Great Britain.*

IN addition to the twenty-three stations referred to in the Report for 1899 instruments have been ordered for the Observatory, Melbourne, the Observatory, Sydney, N.S.W., for Ceylon, for the Johns Hopkins University, Baltimore, the Liverpool Observatory, Bidston, and the Royal Observatory, Edinburgh. The total number of similar installations which may be expected to be in working order before the end of the current year will therefore be twenty-nine. The positions of these are shown on the map (Plate II.).

Registers ending December 31, 1899, referring to Shide, Kew, Cal-

cutta, Madras, Bombay, San Fernando (Spain), Cairo, Mauritius, Batavia, Cape of Good Hope, and Tokio, have been printed and issued as a circular to all co-operating stations, to those who have assisted this committee in their work, and to persons expressing a wish to possess the same. With the object of finding permanent quarters at which a central observing station might be established in England, at the suggestion of this Committee its Secretary, in company with Mr. Horace Darwin, visited the Office of Works, the Treasury, and the Admiralty, and, with Major Leonard Darwin, the Horse Guards. Many sites were discussed, and through the kindness of Colonel Hildebrand, R.E., and commanding officers of the Royal Engineers facilities were given to visit forts and other buildings at Chatham, Folkestone, Porchester, and in the Isle of Wight.

A report on these visits and on those to other places, together with a reference to steps generally which have been taken to find the required site, has been drawn up for the Council of the British Association.

In consequence of the generosity of Mr. M. H. Gray, an instrument room is now being built at Shide.

II. *Analyses of Large Earthquakes recorded in* 1899. *By* John Milne.

1. *Nature and Object of these Analyses.*

In 1897 the Seismological Investigation Committee of the British Association issued to the directors of observatories and other persons in various parts of the world a circular in which they called attention to the desirability of observing earthquake waves which had travelled great distances. It was pointed out that similar instruments should be used at all stations, and the type recommended as being simple to work, and one that yielded results sufficiently accurate for the main objects in view, was described by the Committee in a report (see Reports of the British Association, 1897, p. 137 *et seq.*).

The result of this appeal is that instruments have been forwarded to the following twenty-six stations :—Shide, Kew, Toronto, Victoria, B.C., San Fernando (Spain), Madras, Bombay, Calcutta, Mauritius, Cairo, Cape of Good Hope, Tokio, Batavia, Arequipa, Swarthmore College (Philadelphia), Cordova (Argentina), New Zealand (two instruments), Paisley, Mexico, Beyrut, Honolulu, Trinidad, Melbourne, Sydney, Johns Hopkins University (Baltimore).

For the year 1899 registers were received from the first thirteen of these stations. With the exception of those relating to Toronto and Victoria, these have been communicated to observers by the Committee as a circular. This circular is independent of the present report, but continuous with registers contained in corresponding reports subsequent to 1895.

A glance at these registers, or tables based upon them (see pp. 80–87), shows that while certain earthquakes have evidently shaken the whole surface of our globe, and have probably disturbed the same throughout its mass, there are others of less intensity which have only affected certain parts of the same. For example, one set of earthquakes were only recorded at stations in Western Europe, whilst another set were apparently confined to the Indian Ocean. In the following paper the earthquakes referred to are only those which were recorded in England, from

which it follows that although the largest earthquakes of the year 1899 are discussed many earthquakes which are comparatively smaller have been omitted.

The object of the discussion is to indicate by examples some of the directions in which this extensive system of earthquake observation is increasing our knowledge of dynamical phenomena inherent to the world on which we live.

The plan of the discussion is as follows:—First, those earthquakes which have been recorded at the greatest number of stations, and which have *known* origins, have been selected from the others and analysed separately. To confirm the results towards which these analyses point, references have been made to the more trustworthy records obtained by similar instruments in previous years. The principal objects in view have been as follows. The determination of the velocities with which various types of earth vibrations are propagated and the duration of preliminary tremors at varying distances from origins; to show that earthquake repetition and echoes are fairly frequent and to point out the existence of phenomena for which satisfactory explanations are as yet wanting. In connection with these investigations references are made to hypotheses relating to the physical condition of the interior of our earth.

Second, the results obtained by the above analyses are used as a means to determine the foci of disturbances not included in the first section of this paper. These foci, which for the most part are sub-oceanic, in some instances indicate localities where it would be unwise to lay cables, and where we may expect to find configurations differing from those shown upon our physical maps.

Remembering that very many of the earthquakes discussed represent initial disturbances which were followed by many after-shocks, the map depicting these foci shows the regions on the surface of the earth where in the year 1899 seismic activity was most pronounced.

2. *Velocities of Earthquake Waves.*

The knowledge hitherto at our disposal respecting the velocity of transmission of earthquake motion over long paths has been based on records obtained from instruments differing in type and sensibility, all of which were installed in Europe. The result of this has been that, although the registers led to the determination of average velocities along paths of varying lengths, they never gave actual velocity from point to point. It was seen that along paths from 10° to 90° the velocity of transmission of the preliminary tremors increased rapidly with the lengths of these paths, whilst the average velocity for large waves increased but slightly. With regard to the former my own analyses of heterogeneous materials led to the conclusion that, if the preliminary tremors travelled along paths approximating to chords through the earth, then the average velocity of transmission to a distant station was practically dependent on the square root of the average depth of the chord connecting that station and the earthquake centre. This furnished Dr. C. G. Knott with the hypothesis that the square of the velocity of these particular vibrations, which were in all probability compressional, was a linear function of the depth. With this assumption, and with a given initial velocity, the rate of transmission at any point within the earth could be determined and wave fronts drawn; and by accepting a law respecting the increase of density within

our earth the elasticity governing the transmission of condensational waves could be determined. The following notes show that, although the first conclusion and the consequent hypothesis do not require modification, constants necessary in farther calculations require to be modified.

With regard to the large waves my own assumption was that their apparent increase in velocity with distance might be due to the fact that it was only large waves which, travelling faster than small waves, reached great distances.

The observations brought together in this paper show that this idea has to be abandoned, and in its place we are to accept either the hypothesis of a surface wave which increases its velocity in regions 90° from the focus, or of a distortional wave passing through the earth the outcrop of which gives rise to similar surface undulations.

3. *Sources of Error.*

The phases of earthquake motion here considered are the first preliminary tremors and the first group of large waves, which latter in a seismogram representing an earthquake which has originated at a great distance usually correspond to the maximum movement.

Although near to the origin of an earthquake there is a varying interval of several seconds between the first movements and the shock or shocks, it is the time of occurrence of this latter phase which is taken as the datum to which observations made at great distances from origins are referred. The initial time for all large earthquakes has been a matter of inference. It may be deduced from the times at which clocks have been stopped, or which have been noted with varying degrees of accuracy by survivors in an epifocal district, but more generally it has been deduced from automatic time determinations outside such an area, and subtracting from the same an interval which the shock is assumed to have taken to travel from its origin to the point or points where these chronographic records have been made. The determination of this interval is based upon repeated observations of earthquake velocities made between stations well removed from an epicentre and well outside a meizoseismal area. These figures are important, not only for this particular purpose, but also for completing velocity curves which may represent transmission over the surface and through the material of the whole globe. They have been arrived at by many observers, the last being those given by Dr. F. Omori, who for paths commencing 100 kms. from an origin and extending to distances of 1,000 kms. gives the velocities of 2·2 km. for preliminary tremors and 1·7 km. for large waves, and within these limits the former outrace the latter at the constant rate of 15 seconds per 100 kms.

When we remember that large earthquakes may sometimes originate as practically simultaneous displacements over very large areas, it is seen that the application of the method here considered might easily result in determinations of initial times from a few to some sixty seconds earlier than had really been the case. Errors of this nature would result in a general lowering of the determinations for true velocity of transmission of earthquake motion to distant stations, the deviation from the truth being most marked for the preliminary tremors, and in records referring to transmission to stations comparatively near to an origin.

Another serious error affecting the determination of initial time arises from the difficulty in accurately locating the position of a focus, especially when this is sub-oceanic.

The assumption that for large earthquakes, at least, the origin has been at an epicentre rather than in a region at a certain depth below the surface, is, so far as velocity determinations are concerned, of but small importance. Although all stations have similar instruments, the records from one or two of them indicate that their adjustment has not been similar to that adopted at the remaining stations. Not only should each instrument have a period of 15 seconds, but when its boom is deflected 7 or 8 mm. from its normal position, and then set free, it should take 7 or 8 minutes before returning to rest. If this latter condition has not been observed, an instrument may not respond to the first preliminary tremors, with the result that the time recorded for the commencement of a given earthquake may be registered as one or two minutes after the true time.

Although errors of this order may affect the results deduced from observations within 20° of an earthquake origin, when we deal with paths of greater length, and especially with large waves, the errors in the final results are practically inappreciable.

Another assumption made in connection with velocity determinations is that the group of vibrations and waves as recorded at a distant station extending between the first preliminary tremor and the first maximum—which may extend over any interval up to 100 minutes—were all the result of the principal movement or movements at the origin ; or, in other words, they have the same initial times. To this assumption I do not know of any serious objection. The fact that pronounced phases of movement near to an origin are not only extended in time as they radiate, but are also more or less equalised in their amplitude, frequently renders the determination of corresponding points in seismograms obtained at different stations more or less uncertain. This source of error is sometimes serious.

4. *Preliminary Tremors.*

In the compilation of the following table the only seismograms used are those which show a distinct commencement. Each earthquake is indicated by its British Association Register number, and the locality from which it originated. Following this are the initial letters (see p. 88) of the station or stations at which it was observed. The figures following these initial letters give the number of minutes taken by the preliminary tremors to reach these stations, and the number of degrees between the stations and the earthquake origins. These figures are respectively placed in positions corresponding to the numerators and denominators of fractions. If an initial letter is followed by a zero for a numerator, this indicates that all other time intervals are measured relatively to the observation made at the station represented by the initial letter.

The fewness of these records chiefly arises from these facts : first, they only refer to earthquakes with a known origin ; secondly, the seismograms of small earthquakes recorded at distant stations do not show the preliminary tremors corresponding to those given by large earthquakes ; and lastly, in consequence of air tremors and other causes, the earlier vibrations have in many instances been eclipsed or lost. Their chief merit is that they give for several earthquakes records from point to point, and that we have for the first time records relating to paths which practically extend from an origin to its antipodes.

36 Japan	S. $\frac{16}{87}$	—	—	—	—	—	—	—	—	—	—
119 „	S. $\frac{13}{87}$	—	—	—	—	—	—	—	—	—	—
133 Borneo	S. $\frac{20}{103}$	—	—	—	—	—	—	—	—	—	—
157 Hayti	S. $\frac{8}{60}$	—	T. $\frac{0}{24}$	—	—	—	—	—	—	—	—
193 Japan	S. $\frac{25}{87}$	—	T. $\frac{26}{89}$	—	S.F. $\frac{26}{10[illegible]}$	—	—	—	—	—	—
250 Mexico	—	K. $\frac{13}{86}$	T. $\frac{7}{35}$	V. $\frac{7·5}{33}$	—	—	—	—	—	—	—
263 Japan	—	K. $\frac{24}{87}$	T. $\frac{26}{89}$	V. $\frac{22}{63}$	—	—	—	—	—	—	—
333 Alaska	—	K. $\frac{7}{70}$	T. $\frac{4}{40}$	V. $\frac{0}{16}$	S.F. $\frac{7}{77}$	B. $\frac{19}{105}$	—	—	—	C.G.H. $\frac{20}{165}$	To. $\frac{5}{50}$
337 „	—	K. $\frac{4}{70}$	T. $\frac{0}{40}$	—	—	--	Ba. $\frac{19}{108}$	Ma. $\frac{17}{105}$	—	C.G.H. $\frac{25}{165}$	—
338 „	—	K. $\frac{14}{70}$	T. $\frac{0}{40}$	—	S.F. $\frac{17}{77}$	—	Ba. $\frac{23}{108}$	—	—	C.G.H. $\frac{24}{165}$	—
343 Smyrna	S. $\frac{0}{25}$	K. $\frac{0}{25}$	—	—	S.F. $\frac{1}{27}$	B. $\frac{7}{43}$	—	—	—	C.G.H. $\frac{18}{74}$	To. $\frac{15}{85}$
347 Ceram	S. $\frac{16}{121}$	K. $\frac{16}{121}$	—	V. $\frac{11}{105}$	S.F. $\frac{19}{129}$	B. $\frac{6}{61}$	Ba. $\frac{0}{22}$	—	C. $\frac{4}{50}$	C.G.H. $\frac{21}{105}$	To. $\frac{4}{47}$
381 Mexico	—	K. $\frac{15}{86}$	T. $\frac{9}{35}$	V. $\frac{8}{33}$	—	—	Ba. $\frac{86}{148}$	—	—	—	—

The numbers given in the preceding table have been plotted on squared paper, degrees being measured horizontally and minutes vertically. From the curves thus obtained the average times for preliminary tremors to travel distances of 20°, 30°, 40°, &c. have been determined, and are shown diagrammatically in fig. 1. The initial velocity is taken at 2·2 km. per second. A glance at the table on which this curve is founded indicates that the same can for the present only be regarded as provisional. The incurvation between 50 and 80 degrees is evidently due to errors in observation.

5. *Large Waves.*

The construction of the following table is similar to that given for the preliminary tremors. Following the initial letter of each station, in the position of a numerator, the number of minutes is given which large waves occupied in travelling to that station from the origin or from the isoseist of the locality, the initial letter of which is followed by a zero. The figures corresponding to denominators are the distances of the localities beneath which they appear from the origins of the different earthquakes.

250[1] Mexico	S. $\frac{31}{80}$	T. $\frac{2}{34}$	V. $\frac{0}{30}$	—	—	—	M. $\frac{92}{160}$	—	—	—	—	—
381[1] „	S. $\frac{32}{83}$	T. $\frac{2}{36}$	V. $\frac{0}{32}$	—	—	Ba. $\frac{86}{150}$	—	—	100 89	—	—	—
333 Alaska	S. $\frac{30}{70}$	T. $\frac{13}{40}$	V. $\frac{0}{20}$	S.F. $\frac{36}{77}$	B. $\frac{47}{105}$	—	M. $\frac{81}{145}$	—	C.G.H. $\frac{79}{165}$	To. $\frac{17}{50}$	—	—
337 „	S. $\frac{20}{70}$	T. $\frac{0}{40}$	—	S.F. $\frac{22}{77}$	B. $\frac{34}{105}$	Ba. $\frac{50}{108}$	—	Me. $\frac{7}{49}$	C.G.H. $\frac{69}{165}$	—	Ma. $\frac{39}{105}$	—
338 „	S. $\frac{19}{70}$	T. $\frac{0}{40}$	—	S.F. $\frac{22}{77}$	B. $\frac{35}{105}$	Ba. $\frac{53}{108}$	M. $\frac{64}{145}$	Me. $\frac{6}{49}$	C.G.H. $\frac{61}{165}$	—	—	—
347 Ceram	S. $\frac{70}{121}$	—	V. $\frac{73}{105}$	S.F. $\frac{30}{132}$	B. $\frac{28}{62}$	Ba. $\frac{16}{22}$	M. $\frac{40}{73}$	—	C.G.H. $\frac{60}{105}$	To. $\frac{18}{47}$	—	C. $\frac{18}{50}$
343 Smyrna	S. $\frac{0}{25}$	—	—	S.F. $\frac{10}{27}$	B. $\frac{14}{43}$	—	M. $\frac{34}{65}$	—	C.G.H. $\frac{29}{74}$	To. $\frac{30}{85}$	—	—

[1] The times at the origin for these two earthquakes were 21 and 22 min. before Victoria.

When these observations are plotted on squared paper it is found that they practically lie on the straight line referring to large waves in fig. 1, indicating that this form of movement passes from its origin to its antipodes with a constant arcual velocity of 3 km. per second. If, however, the direction of propagation has been along a diameter, the average velocity becomes 1·9 km. per second. The time taken for an earthquake to travel from its origin to its antipodes, whether it does so as a surface wave or as a mass wave, is about 110 minutes.

One modification to this general statement respecting a constant velocity rests on the fact that repeated observations made within ten degrees of an earthquake origin have shown that the large wave velocity within that region is about 1·8 km. per second. Whatever the conditions may be which give rise to this increase in velocity in a wave as it radiates from its origin, it seems probable that the converse would take place as it approached its antipodes, while the maximum velocity should be sought for in the equatorial or quadrantal[1] region of the earthquake's transit. Inasmuch as curves drawn for the Alaskan and Ceram earthquakes show that between 70° and 110° from their respective origins velocities may reach 4 km. per second, and that many earthquakes indicate an increased average velocity as their paths increase up to 110° in their lengths, there are strong reasons for suspecting that the suggested phenomena may exist. The comparatively small initial velocity and the slightly increased quadrantal velocity above the average arcual velocity are indicated in fig. 1 by dotted lines; but whether this modification can be retained remains to be determined by further observations. That the average arcual velocity between 0° and 90° is practically 3 km. per second finds confirmation in the records for earthquakes Nos. 36, 83, 100, 119, and 193, originating in Japan, 133 and 134, originating near Borneo, and 105, from N.E. India, all of which were recorded by the same instrument in the Isle of Wight.

6. *Interval between the First Tremor and the Maximum Motion.*

In the British Association Reports for 1898, pp. 221–224, I discussed a table showing the duration of preliminary tremors or the interval in time between the first tremor and the *commencement* of the large wave phase of motion at different distances from a number of known origins. One object of the discussion was to establish a working rule enabling an observer to determine from the inspection of a single seismogram the distance of an origin from the station at which such a record had been obtained. Inasmuch as the table was to a great extent based upon descriptions of records obtained from different types of instruments which had different degrees of sensibility, the results obtained could not be expected to be more than approximately correct. The following table, which gives the time in minutes by which the first tremor has outraced the maximum movement over paths of varying lengths, is based on measurements made on seismograms obtained from similar instruments. These intervals not only enable us to correct the working rule indicated above, but, as it will be shown, they enable us to check the accuracy of the curves relating to the arcual velocity of preliminary tremors and large waves.

[1] This word means the district 90° distant from the earthquake origin.

Intervals between the First Tremor and the Maximum Motion.

No.	Date	Origin	Observing Stations indicated by initial letters and time intervals and distances, as $\frac{\text{Minutes}}{\text{Degrees}}$
36	August 30, 1896	Japan	S., $\frac{40}{84}$.
56	October 31, 1896	Tashkent	S., $\frac{13}{45}$.
83	February 6, 1897	Japan	S., $\frac{34}{86}$. Record not clear.
119	August 4, 1897	,,	S., $\frac{46}{86}$.
131	September 17, 1897	Tashkent	S., $\frac{15}{45}$.
132	September 17, 1897	,,	S., $\frac{15}{45}$.
133	September 20, 1897	Borneo	S., $\frac{52}{103}$.
134	September 20, 1897	,,	S., $\frac{60}{103}$.
157	December 29, 1897	Hayti	S., $\frac{29}{62}$. T., $\frac{3}{24}$.
163	January 29, 1898	Asia Minor	S., $\frac{12}{25}$.
189	April 15, 1898	California	T., $\frac{5}{35}$?
193	April 22, 1898	Japan	S., $\frac{35}{86}$ (not clear). T., $\frac{35}{89}$.
249	January 22, 1899	Greece	S., $\frac{10}{21}$. K., $\frac{7}{21}$.
250	January 24, 1899	Mexico	K., $\frac{40}{80}$. T., $\frac{15}{34}$. V., $\frac{14}{30}$. P., $\frac{15}{30}$.
333	September 3, 1899	Alaska	K., $\frac{30}{70}$. T., $\frac{18}{40}$. V., $\frac{5}{20}$. S.F., $\frac{34}{77}$. B., $\frac{33}{105}$? To., $\frac{15}{50}$. C.G.H., $\frac{65}{105}$
337	September 10, 1899	,,	K., $\frac{35}{70}$. T., $\frac{13}{34}$. C.G.H., $\frac{43}{165}$? B., $\frac{41}{105}$. S.F., $\frac{31}{77}$. Me, $\frac{28}{49}$.
338	September 10, 1899	,,	K., $\frac{30}{70}$. T., $\frac{27}{34}$? Me., $\frac{20}{49}$. Ba., $\frac{55}{108}$.
343	September 20, 1899	Aidin	S., $\frac{9}{25}$. C.G.H., $\frac{15}{74}$? B., $\frac{15}{43}$. K., $\frac{6}{25}$. To., $\frac{32}{85}$.
347	September 29, 1899	Ceram	S., $\frac{60}{121}$. C.G.H., $\frac{41}{105}$. Ba., $\frac{4}{22}$. B., $\frac{10}{62}$? V., $\frac{70}{105}$?
381	January 20, 1900	Mexico	K., $\frac{39}{83}$. T., $\frac{14}{36}$. V., $\frac{13}{32}$.

These observations have been plotted upon squared paper, and their mean position determined. This is shown in fig. 1 as Curve No. III.

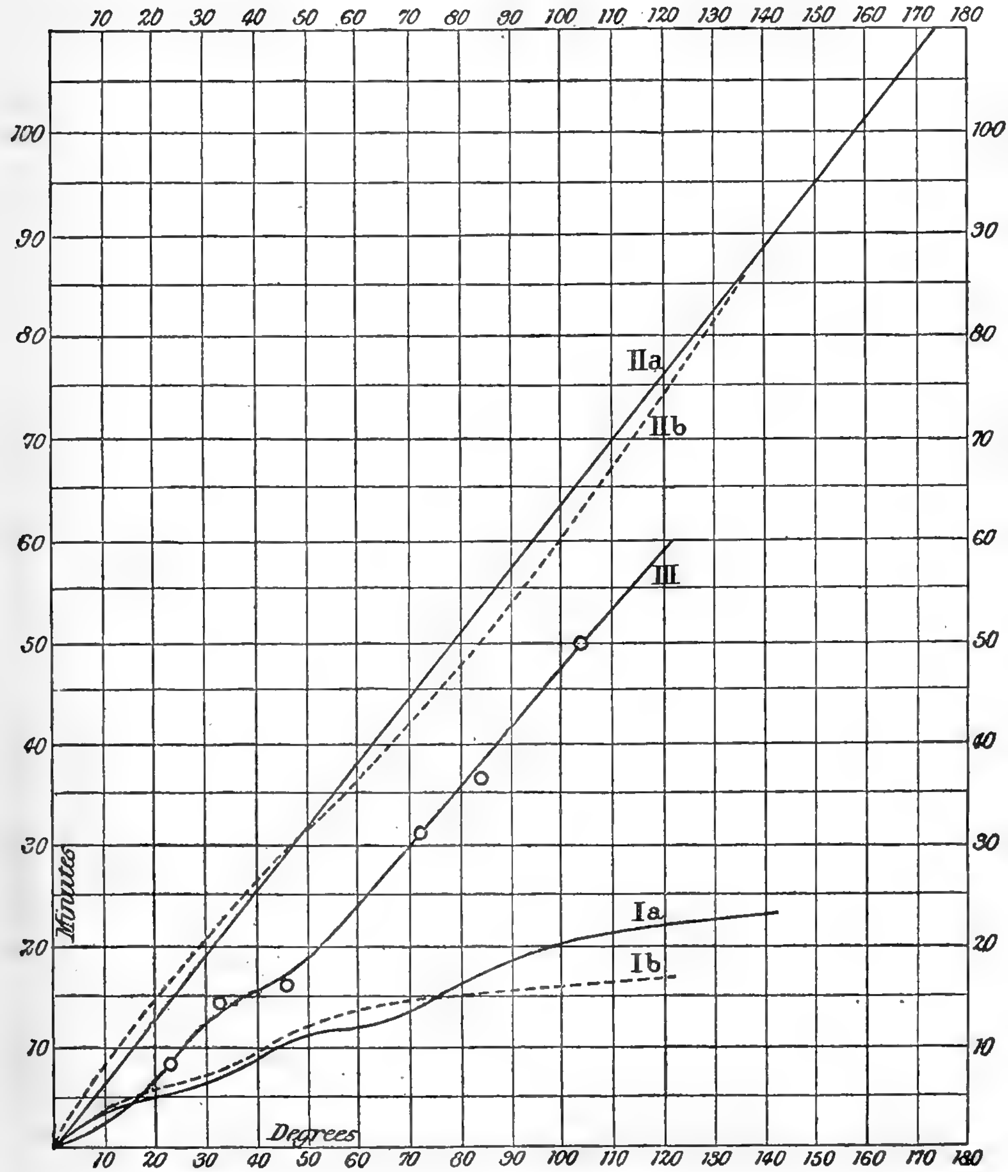
On Curves I, II, and III, fig. 1.—Although in fig. 1 we have three curves which have been obtained from partly independent data, it will be observed that any one of them might have been obtained from the other remaining two. Although errors exist in all our data, these are probably least in the figures relating to the arcual velocity of large waves and the duration of preliminary tremors. By subtracting the ordinates for the latter curve, marked III, from those of the first curve, marked II, the curve I *b* is obtained. This should coincide with I *a*. It hardly does so ; but if the second incurvature of I *a*, lying between 50 and 80 degrees, be effaced as probably doubtful the agreement between these two curves becomes closer.

7. *Earthquake Recurrence.*

It would be naturally expected that if the large waves of earthquakes were simply surface disturbances, we should find in the seismograms obtained at stations far distant from origins not only records of the waves which had travelled over the shortest paths, but also a record of those which had travelled in an exactly opposite direction. The supposition that these latter records were without existence has been used as evidence in support of the hypothesis that all the movements of a large earthquake passed through the earth. Mr. R. D. Oldham, in his account of the Indian earthquake of 1897, however, shows that in the seismo-

grams obtained in Edinburgh, Shide, Leghorn, Rocca di Papa, and Catania there are excrescences succeeding the maxima movements at

FIG. 1.



Arcual Velocities.—Ia. Preliminary Tremors by direct observation; Ib. Preliminary Tremors deduced from IIa and III; IIa. Large Waves if the Velocity is constant; IIb. Large Waves if the Velocity varies; III. Intervals by which Preliminary Tremors outrace Large Waves.

times we should expect them to occur on the supposition that they had travelled round the world from their origins on the longest paths.

Without discussing the merits of the particular seismograms here referred to, we must bear in mind that it is possible for body waves to give rise to repetitions by reflection just as easily as two trains of waves

coming round the surface of the world in opposite directions. Further, the repetition at a given station as a reflection of a disturbance at the antipodal point of its origin might occur at an interval of time after the first movement not very different from that separating the two surface trains.

Such a possibility indicates that seismic repetitions cannot be exclusively used to support the hypothesis of surface radiation. Examples of earthquake recurrences are given in the following table. The first column gives the numbers of the earthquakes in the British Association registers and their origins. Where the position of an origin is not known from observations made in its vicinity its latitude and longitude are determined by one of the methods described in the succeeding sections of this report (see pp. 79–80). Such determinations must only be regarded as approximations. The second column gives the arcual degree-distances of the origins from the observing stations referred to in the third column by their initial letters. In this third column there is also noted the number of minutes' interval between the maximum motion and its apparent repetition. The fourth column gives the calculated distance of the observing station from the origin, and the nearness to which it approximates to the corresponding figures in the second column is evidently an indication of the value of these observations in determining seismic foci. The basis for these calculations is that a surface-wave travels 180 degrees in 105 minutes. In the last column the letters G, I, and B (good, indifferent, and bad) indicate that the determinations in the fourth column lie within 10°, 20°, or more than 20° from those in the second column, which latter figures, however, it must be remembered, are themselves but approximations.

No. of Earthquake and its Origin	Distance to Origin in Degrees	Repetition Interval in minutes at a given Station	Distance to Origin determined from Repetition Interval	Character of the Determination
	°	m.	°	
119. Japan . .	87	85 S.	96	G
140. . . .	110	105 S.	82	B
278. 30° N. 70° W.	60	122 S.	68	G
309. 60° N. 180° W.	70	132 S.	62	G
	70	121 K.	70	G
	160	144 C.G.H.	52	B
333. W. of Alaska .	16?	212 V.	0	G
	40	159 T.	40	G
	70	127 to 145 K.	66 to 52	G
337. W. of Alaska .	40	129 T.	62	B
	165	75 C.G.H.	108	B
	77	185 S.F.	18	B
338. W. of Alaska .	40	163 T.	38	G
	165	123 C.G.H.	70	B
	77	128 S.F.	66	I
343. Smyrna . .	25	73 S.	108	B
347. Ceram . .	121	59 S.	120	G
	121	78 K.	106	I
	105	80 V.	102	G
354. 5 S. 130 E. or 20 S. 100 E.	120	70 S.	110	G
	100	63 C.G.H.	116	I
	110	95 V.	90	I
355. Like 354. .	120?	60 S.	118	G
364. 20° N. 170 E.?	106	73 M.	108	G

We have here twenty-four determinations, out of which thirteen are considered as being good, four as indifferent, and seven as bad. The three bad determinations for earthquake No. 337 may be explained by the assumption that we have here been dealing with markings due to secondary shocks which simulated seismic repetitions, a view that is strengthened when we refer to the seismograms of this earthquake. It must also be noted that No. 337 was less than Nos. 333 or 338, from which it may be inferred that the original impulse was not sufficiently great to give rise to duplications. The fact that the Cape of Good Hope records for 309 and 338 are bad may arise from the circumstance that this station was within a comparatively short distance of the antipodes of these shocks, and therefore any wave coming from that point would be eclipsed in the records of the main disturbance. The remaining two bad determinations may be explained in the same manner that those for No. 337 have been explained.

The Victorian record for No. 333 is of particular interest as indicating that the time taken for an earthquake to travel round the world or to traverse two diameters slightly exceeds 210 minutes.

When considering whether these repetitions are to be regarded as surface waves or as mass waves reflected from an antipodes, a feature not to be overlooked is their smallness. To illustrate this I here give a table for the thirteen good observations showing the amplitudes in millimetres of the primary disturbances and those of their repetitions, together with the arcual distance each may be supposed to have travelled.

B. A. No.	Primary		Repetition	
	Distance	Amp.	Distance	Amp.
	°	mm.	°	mm.
119	87 S.	> 16	273	1·5
278	60 S.	2·5	300	·5
309	70 S.	3	290	·5
	70 K.	2·5	290	·5 ?
333	20 V.	> 16	340	·75
	40 T.	> 17	320	·5
	70 K.	10	290	·5 ?
338	40 T.	> 17	320	·75
347	121 S.	3·5	239	1·5
	105 V.	2	255	·5
354	120 S.	2	240	·5
355	120 S.	1·5	240	·5
364	106 M.	3	254	1

It is satisfactory to note that the magnitude of these repetition amplitudes fairly accords with what might be anticipated (see p. 70).

8. *Amplitude in relation to Distance from an Origin.*

In the following table amplitudes are expressed in millimetres and occupy a position corresponding to the numerator of a fraction, whilst in the position of a denominator distances from origins are expressed in degrees. Observing stations are indicated by their initial letter or letters.

Inasmuch as there are reasons for believing that the instruments giving the subjoined records have not in all cases been adjusted to have the same frictional resistances and as these records are few, the result to which they point must be received with caution. When they are

plotted as curves it is seen that each has the same general character. The rate at which amplitude at first decreases is about ·2 mm. per degree of travel. Earthquakes like Nos. 343 and 347 from whatever may have been their amplitude in the epifocal district, are reduced to an amplitude of 4 mm. after about 50° of travel. Larger earthquakes, like Nos. 337, 344, and 345, travelled 80° or 90° before their amplitude sank to this quantity; whilst the largest of all, Nos. 333 and 338, show an amplitude of more than 4 mm. after travelling nearly halfway round the world. From an amplitude of 4 or 5 mm. the rate of decrease becomes less and less. For example, the amplitude of No. 337 between 77° and 105° falls from 5 mm. to 3 mm., or at the rate of ·07 mm. per degree; whilst from 105° to 165° the rate at which amplitude decreases has been ·01 mm. per degree at travel.

250. Mexico .	S. $\frac{6}{80}$	K $\frac{4·5}{80}$	T. $\frac{8}{34}$	V. $\frac{>17}{30}$	—	—	—	—	—	—	—	P. $\frac{6}{34}$
344. Alaska .	S. $\frac{5}{70}$	—	T. $\frac{>17}{20}$	—	—	B. $\frac{0·5}{105}$	—	M. $\frac{·75}{145}$	—	—	To. $\frac{2·5}{50}$	—
345. " .	S. $\frac{5}{70}$	—	T. $\frac{>17}{20}$	—	—	B. $\frac{0·5}{105}$	—		—	—	—	—
333. " .	S. $\frac{>17}{70}$	—	T. $\frac{>17}{40}$	V. $\frac{>17}{20}$	S.F. $\frac{20}{77}$	B. $\frac{>17}{105}$	—	M. $\frac{>17}{145}$	—	C.G.H. $\frac{10}{165}$	To. $\frac{1}{50}$	—
337. " .	— —	—	T. $\frac{20}{40}$	—	S.F. $\frac{5}{77}$	B. $\frac{3}{105}$	—	—	M. $\frac{4}{49}$	C.G.H. $\frac{2}{165}$	—	—
338. " .	— —	K. $\frac{>17}{70}$	T. $\frac{>17}{40}$	—	S.F. $\frac{20}{77}$	B. $\frac{9}{105}$	—	M. $\frac{4}{145}$	—	C.G.H. $\frac{10}{165}$	—	—
347. Ceram .	S. $\frac{2·5}{121}$	—	—	V. $\frac{2}{105}$	—	B. $\frac{1}{62}$	Ba. $\frac{10}{22}$	M. $\frac{1·5}{73}$	—	C.G.H. $\frac{0·5}{105}$	To. $\frac{5}{47}$	—
343. Smyrna	S. $\frac{9}{25}$	—	—	—	—	B. $\frac{·4}{43}$	—	M. $\frac{1}{65}$	—	C.G.H. $\frac{6}{74}$	To. $\frac{4}{85}$	—

These slow rates of decrease indicate that it is reasonable to suppose that the large waves of earthquakes may reach distant stations by travelling in opposite directions round the world.

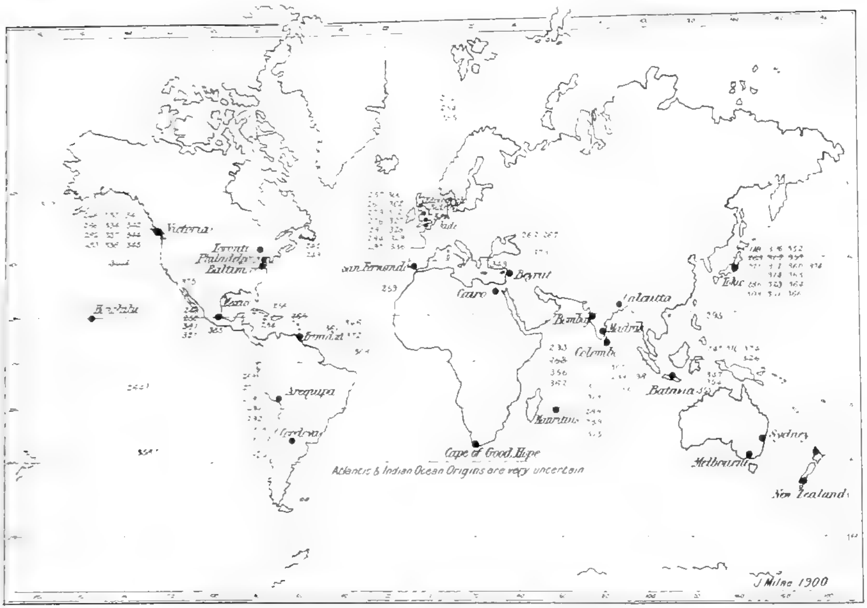
If the large waves of earthquakes are merely surface waves, it would be expected that oceans would exert a marked damping effect upon their amplitude. Indications of this apparently exist in the records for earthquakes Nos. 337, 338, and 347 (also see earthquake 263, p. 81). In the first the amplitude for Toronto is greater than that observed in Mexico, the path to the former being across North America, and the latter being suboceanic. In No. 338 the record for Mauritius is less than that for the Cape of Good Hope. In No. 333 this condition is, however, reversed. Lastly, in No. 347 the Shide record, which refers to a comparatively long continental path, is greater than the records for Victoria, the Cape of Good Hope, Bombay, or Mauritius, the shorter paths to which are beneath oceans. Although, for reasons already stated, stress cannot be laid upon these observations, the latter at least suggests that we are dealing with surface waves rather than with mass waves.

9. *Arcual Velocity in relation to Surface Configuration of the Earth.*

With the object of determining whether large waves are propagated more quickly over continents than over ocean beds, whether the rate of transmission along mountain axes is greater than in directions transverse to the same, and generally to determine whether there are directions over or through our globe in which motion is transmitted more rapidly than in others, the following table has been prepared. The apparent surface

The Large Earthquakes of 1899.

Origins are indicated by their B.A. Register numbers. Stations with similar horizontal pendulums (Milne type) are named.



Illustrating the Report on Seismological Investigation.

velocities indicated in kilometres per second are from the isoseist of the place indicated by its initial letter to the place beneath which it is written. These latter places in the top line are also indicated by their initial letters The letter O refers to a velocity measured between an origin and the place named in the upper line.

	S.	T.	V.	SF.	B.	Ba.	M.	Me.	CGH.	To.	C.
250. Mexico .	T. 3·1	Me. 2·7	Me. 2·6	—	—	O. 3·2	O. 3·2	—	—	—	—
381. „ .	T. 3·2	Me. 2·6	Me. 2·6	—	—	—	—	—	—	—	—
333. Alaska .	T. 3·2	V. 3·4	—	T. 3·1	T. 3·6	T. 2·9	B. 2·1	—	T. 3·4	V. 3·7	—
337. „ .	T. 2·7	—	—	T. 3·1	T. 3·6	T. 2·3	—	T. 2·3	T. 3·5	—	—
338. „ .	T. 2·9	—	—	T. 3·1	T. 3·4	—	B. 2·5	T. 2·7	T. 3·7	—	—
347. Ceram .	Ba. 2·3	—	Ba. 2·1	—	Ba. 2·6	—	Ba. 2·1	—	Ba. 2·5	Ba. 2·6	Ba. 2·8
343. Smyrna .	—	—	—	S. 0·3	S. 2·3	—	S. 2·1	—	S. 3·1	S. 3·7	—
193. Japan .	O. 2·6	O. 2·8	—	—	—	—	—	—	—	—	—

As it is difficult to picture the directions of great circle paths outside equatorial regions, these are shown with the above velocities and the earthquakes to which they refer in the accompanying map (Plate II.). A line not referred to in the above table is that for earthquakes numbered 36, 83, 100, and 119, which originated in Japan and travelled to the Isle of Wight with an average velocity of 2·9 kms. per second.

An inspection of the map (Plate I.) shows that the apparent velocities over long paths are greater than those over short paths. Velocities across the Pacific are apparently lower than those across the Atlantic, and those across Northern Asia to Shide are lower than those across North America to Shide. Between Mexico and Victoria along the strike of the chief North American anticline the velocity of transmission is the same as that between Mexico and Toronto. Along paths terminating at the Cape of Good Hope the rate of transmission has been high, whilst on those terminating at Mauritius, excepting that referring to the long path for earthquake 250, the velocity of propagation appears to be low.

There does not appear to be any indication that direction of propagation is related to speed, and although earthquake 381 was larger than 250, and 333 and 338 were larger than 337, we do not seem to have any definite evidence that velocity of propagation is connected with the intensity of the initial disturbance.

Taking the results of this investigation generally, we are hardly in a position as yet to draw definite conclusions, and must wait for further observations.

10. *Earthquake Echoes.*

In the British Association Report for 1899, p. 227, I drew attention to the fact that in seismograms where a group of large vibrations corresponding to a shock or shocks at an origin is pronounced, this is frequently succeeded by a set of fairly similar movements. These latter impulses, which may be repeated, but with decreasing intensity, many times, I provisionally called earthquake echoes. Although earthquake repetitions (see pp. 66–69) which succeed their primaries at very irregular intervals may possibly be antipodean reflections of mass waves, they must not be confounded with the so-called echoes which succeed the maxima movements at fairly regular intervals.

The following table gives time intervals in minutes between a number

of shocks and their first echoes, together with their respective amplitudes expressed in millimetres. These records are from similar instruments.

B.A. No.	Origin and its Distance		Amplitudes Primary	Echo	Interval	Observing Station
		°	mm.	mm.	Mins.	
36	Japan .	84	5	5	9	Shide
56	Tashkent	46	6	4	3	,,
83	Japan .	87	>7	>7	8	,,
119	,, .	87	17	10	7	,,
157	Hayti .	62	2·5	2·5	7	,,
,,	,, .	24	6	3	3	Toronto
163	Asia Minor	25	3	4	5	Shide. Record not clear
189	California	75	2	3	2	,,
,,	,,	or	2	1	7	,,
193	Japan ,,	86	5	3	3	,,
250	Mexico .	80	5	5	3	,,
,,	,, .	80	6	7	7	Kew. Doubtful
,,	,, .	34	7	8	5	Toronto
,,	,, .	30	17	9	5	Victoria
322	Concepcion		2·5	1·5	6	Toronto
333	Alaska .	20	>17	17	22	Victoria
,,	,, .	40	17	12	22	Toronto
,,	,, .	70	10	7	5	Kew
,,	,, .	105	17	15	4	Bombay
,,	,, .	165	7	7	9 or 20	Cape of Good Hope
,,	,, .	77	17	10	5	San Fernando
337	,, .	40	18	7	25	Toronto
,,	,, .	105	3	2	3	Bombay
338	,, .	40	>17	15	25	Toronto
,,	,, .	70	17	7	5	Kew
,,	,, .	145	4	4	8	Mauritius
,,	,, .	165	11	10	17	Cape of Good Hope
,,	,, .	105	8	7	4	Bombay
,,	,, .	49	17	7	3	Mexico
343	Smyrna .	25	7	8	5	Shide
,,	,, .	85	3	3	3	Tokio
,,	,, .	74	7	5	5	Cape of Good Hope
,,	,, .	43	4	4	3	Bombay
,,	,, .	25	5	5	4	Kew
344	Alaska .	70	4	3	4	Shide
,,	,, .	20	17	7	4	Victoria
345	,, .	70	5	4	5	Shide
,,	,, .	20	>17	7	4	Victoria. Larger than 344
381	Mexico. At Victoria and Toronto the chief motion is followed by three reinforcements at intervals of 3 minutes. At Kew there are two at intervals of about 3 minutes.					

The second group of waves, giving the large interval for the Cape of Good Hope in 333 and 338, may possibly refer to the motion which reached that station by the longest path round the earth.

If so regarded, these entries do not refer to echoes, but to repetitions. The large entries for Victoria and Toronto on account of the comparative nearness of these places to the origins of earthquakes 333, 337, and 338,

cannot, however, be so regarded. Between these extremely large reinforcements it must not be overlooked that there are others of less magnitude separated by intervals of from two to four minutes.

All that we can conclude from an inspection of the above table is that after all sensible motion of a large earthquake has ceased horizontal pendulums, whether they are situated near to its origin or at a great distance from the same, indicate that the earth waves at intervals of from two to six minutes show marked increments in amplitude. The earthquake does not die out gradually, but by surgings. In its latter stages, for intervals of one or two minutes, the ground may be entirely at rest, after which movement recommences. This alternation of rest and movement may be repeated many times.

If it can be admitted that large earthquakes result from the collapse of ill-supported portions of the earth's crust upon a more or less plastic layer beneath, it may be imagined that rest is attained by a series of more or less regular surgings, which are propagated to distant places to disturb horizontal pendulums in the way observed.

11. *The Nature of Large Waves.*

To explain the existence of the large waves of earthquakes we are at present left to choose between two hypotheses. One is that the large waves of earthquakes are disturbances travelling partly under the influence of gravity over the surface of our earth, and the latter that they represent the outcrop of distortional waves passing through its mass.

Near to the origin of a large earthquake earth waves are visible ; some distance away their existence has been inferred from the wave-like motion seen on the tops of forests, at a distance of 300 miles, and even at very much greater distances the feeling occasioned by the moving ground is similar to that which is felt upon a raft moved by an ocean swell. Bracket seismographs, hanging pictures and lamps, water in vessels, ponds, and even in lakes, do not move with their natural periods, but are clearly influenced by a forced tilting. Finally, even as far as the antipodes of an origin, the character of motion assumed by horizontal and other pendulums shows that this is due to slow but repeated changes in the inclination of their supporting foundations.

If we except the movements observed within the epifocal area, all the other movements are as explicable by the assumption of the outcrop of mass waves as they are by the assumption of surface radiation.

The explanation that these waves have an increased velocity in their quadrantal region (assuming such to be the case) may perhaps rest on the fact that we are not dealing with radiation in uniformly widening rings, as would be the case over a plane surface. The condition in this region is such that energy is transferred from ring to ring, the diameters of which are but little different from each other. Radiation from a pole to its antipodes over a spherical surface may be likened to that of a wave which runs along a channel, which expands for half its length and then contracts.

The phenomena which give the greatest support to the idea of surface radiation are, first, the existence of earthquake recurrences or waves which have travelled from an origin to a distant station in opposite directions round the world, the one arriving last having its amplitude reduced to expected dimensions ; and second, the observations which show that waves travelling over a continental surface are not so rapidly reduced in magni-

tude as those which have been propagated over the beds of deep oceans. Were the large waves of earthquakes mass waves, it is assumed that the damping effect of oceanic waters would be insignificant.

When considering the large waves to be distortional mass waves, an observation of importance is that they travel from their origin to their antipodes in about 110 minutes (see fig. 1). If the path was along a diameter, the average velocity of propagation must therefore have been 1·9 km. per second, which is practically the so-called initial velocity. The close correspondence of these two velocities suggests the idea that there has not been any symmetrical change in the velocity of propagation of waves through the earth with regard to its centre, or, in other words, the large waves have had a diametral velocity which is practically constant. This idea of a constant velocity for all depths indicates that arcual and diametral velocities should be equal, which is not the case. An escape from the dilemma is to suppose that the large waves do not pass through the earth, but round its surface.

12. *Criticisms and Analyses by Dr. C. G. Knott.*

In reference to the conclusion implied in the last paragraph, Dr. Knott remarks that it does not necessarily follow from the premises, the initial speed referred to being an arcual speed, or a speed for short distances from an origin through the surface layers. When a disturbance travels straight down it very soon gets probably into more homogeneous materials beneath the crust. It may therefore be a mere coincidence that the average speed along a diameter may come out almost exactly the same as the arcual speed in the crust.

The evidence seems to show that once you get into the nucleus proper, the speed of the large waves decreases with depth. But this does not prevent the speed suffering a distinct increase when the disturbance passes from the lower layers of the crust into the higher layers of the nucleus. That the arcual speed should be 1·9 for small arcs, and then become on the average three when the arc is half a circumference, seems to be an immeasurably more difficult thing to understand than that the speed downwards should first increase and then decrease as the depth increases. A not improbable change in the nature of the material could easily account for the latter variation; but it is difficult to see how a surface wave of the size of the large waves could gain in speed as it ran round the earth.

Writing more generally respecting the propagation of large waves, Dr. Knott says:—

I have looked pretty carefully into your numbers and curves, and now I shall indicate some of my conclusions. As you have pointed out, the one doubtful point is the precise instant at which the disturbance began, also to some extent the exact position of the origin. I take your determinations as being as accurate as they can be obtained, and proceed to consider the speeds indicated. The accompanying tables will show you what I have tried to do. Take the Alaskan group, the most complete of all you have. It is gratifying to find how similar the results are for the three different earthquakes. The greatest discrepancy is in the two numbers for the Batavian records. It is curious that these time records do not fit well into the general scheme. Can there be any mistake? The arcual speed indicated is distinctly smaller than we find in all the other

cases, except the case of Mauritius. If there is no mistake in calculating the times, then the disturbance travels comparatively slowly along the Alaskan Batavian route. This route, *if it lies near the surface*, is almost wholly beneath the deeps of the North Pacific. But then, on the other hand, the Alaskan Mauritius route is also a comparatively slow route, and it lies further to the west, under Siberia, India, and the Indian Ocean. Still, these two routes are in the same quarter of the globe, so that a similar value for the speed is not unlikely. It may be not merely a question as to whether sea or land is overhead, but may depend on the general character of the rocky material. These two routes left out of account, there is a very striking constancy in the value of the arcual speed calculated for these various routes. In the four routes to Shide, San Fernando, Bombay, and Cape of Good Hope, the great circles pass all very near the poles. It is beautiful to see how well these four polar routes agree. With the somewhat scanty material you have to hand, I doubt if you would be at all warranted in making any deductions as to variations of speed. The Alaskan results suggest a constant value for the arcual speed. The same constancy is indicated in the Mexican earthquakes, but the value comes out distinctly smaller than in the Alaskan quakes. Why is this? Still thinking of great-circle routes, we see that there cannot be much difference between the Mexican Batavian and the polar routes from Alaska, unless, of course, the former goes preferably by way of the South Pole. But that possibility is not considered in calculating the speeds. If we took it that way the speed would come out larger in the ratio of 210 to 150 or 7·5, giving 1·9 instead of 1·4, a remarkable coincidence truly. The Mauritius number will also be increased in much the same ratio. But what are we to make of the others? No, I think we must get at an explanation of the much smaller speeds associated with the Mexican earthquakes in some other way. Is it possible that the depth of the seismic focus might have something to do with it? Have you any facts to guide you to an estimate of the probable depth?

And now pass on to the Ceram quake. Here the constancy, so marked a feature in the other cases, no longer holds. There is an undoubted increase in the arcual speed over the longer arcs. The most striking feature is the smallness of the Mauritius route speed as compared with that associated with the Cape of Good Hope route; for there cannot be much difference in the routes for the greater part of the way. But did not Mauritius give a too small value in the Alaskan earthquake also? Again, I ask, is there no possibility of an error in the time estimate? Ceram Victoria and Mexico Batavia give approximately the same value for the arcual speed—a point which tells in favour of the accuracy of the time estimates, for the routes are very different in the two cases. Leaving out of account all but the broad features, we may conclude that the speeds (arcual) associated with the Alaskan are distinctly greater than those associated with the Mexican and Ceram earthquakes. But I confess I can give no satisfactory explanation of this, nor can I see why Batavia and Mauritius should give smaller values than the others in the Alaskan group, and why Cape of Good Hope and Shide should give comparatively large values in the Ceram group.

And now let us see what comes of taking the chord as the approximate path of shortest time. Interpreted in this way the results indicate that the waves must go diametrically through the earth at a much slower average

rate than along a course near the surface. Thus, from the Alaskan group we should infer an average diametrial speed of about 2·2 km. per sec.; from the Mexican group about 1·8; and from the Ceram group about 2·5. This suggests that the speed of propagation along a diameter depends upon the particular diameter considered—a very curious result surely, unless, of course, the depth of the focus below the surface be very different in the different cases.

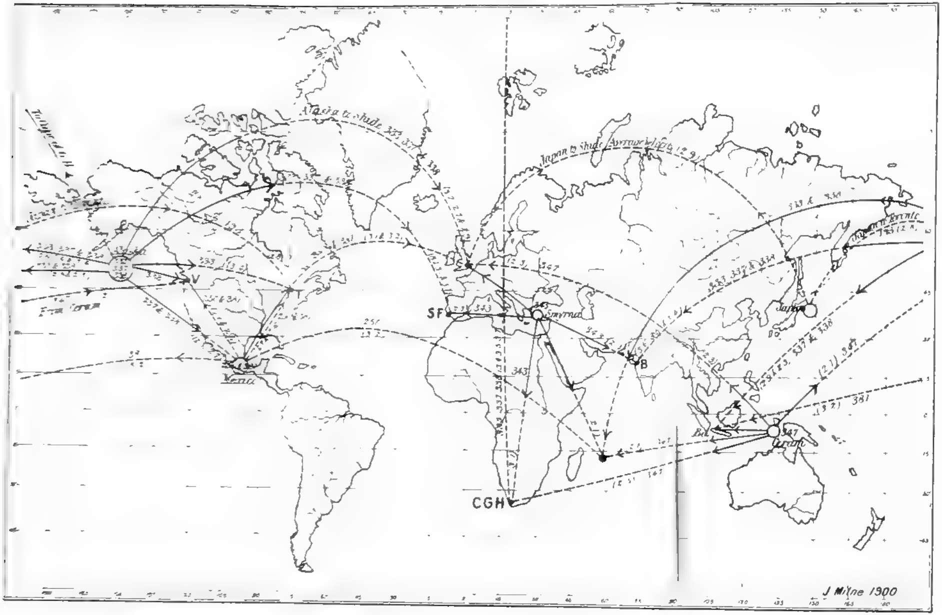
As regards the general question of the diminution of speed at greater depths, all we can say is that it is not impossible. True, the result is unexpected, seeing that there can be little doubt that the preliminary tremors travel quicker at the greater depths. But then it is also certain that the elastic constants involved in the transmission of the two types of waves must be essentially different, and there is no necessity for them to obey similar laws of variation with depth. In my 'Scottish Geographical Magazine' article I pointed out that the bulk modulus might increase at a much quicker rate than the density, whereas the rigidity might increase at much the same rate. To meet the new need we have merely to assume that the rigidity does not increase so quickly as the density. We know that the density increases with the depth, and we know nothing whatever about the elastic constants except what we learn from seismic phenomena. It was, in fact, with feelings of surprise that we first recognised the high speeds of earthquake disturbances through the body of the earth. That another type of wave should travel more slowly at the greater depths should not therefore be matter of any surprise, although certainly remarkable.

The hypothesis that the large waves really pass along brachistochronic paths seems to require that the speed diminishes with distance from the centre. This means that the paths are convex outwards, concave towards the centre. Hence the paths to points within 90° of the origin will tend to follow more or less closely the arc of the outer crust. When the arcual distance exceeds the quadrant, then the paths begin to pass through deeper parts of the earth, and the fall off in the value of the average speed becomes more apparent. This is precisely what is indicated in the values deduced from the Alaskan group, since it is not till the arc exceeds 105° that the value of the calculated average speed shows marked diminution. The Mexican group shows the same feature, but not so the Ceram earthquake. Still it is only one against five, and we shall be safer in following the five.

Comparing the two hypotheses, the surface wave and the brachistochronic path, we see that up to distances of a quadrant or so they give much the same result, because the brachistochronic path is largely confined to the surface layers. As regards greater distances the evidence in hand is not very clear. Increased 'arcual speed' is hinted at, and this, if it exist, is a serious stumbling-block in the way of accepting the surface wave theory. But at best the increase is small, and, except in the case of the Ceram quake, really too small to build any conclusions upon. I should rather be inclined to say that the evidence so far is in favour of a practically constant 'arcual speed' over all distances. But I still entertain strong suspicion of the possibility of surface waves of the magnitude required being transmitted over the earth's surface. If we take the values of the arcual speeds in the Ceram earthquake as being accurate, we meet what seems to me to be an insurmountable difficulty in the surface wave theory. On the other hand, we have no insurmountable difficulties if we

Apparent Paths of the Large Waves of Earthquakes from five origins (indicated by circles) to various observing stations.

The Alaskan origin for earthquakes Nos. 333, 337, and 338 might possibly be moved 10° to the east. The velocities given in kms. per sec. and placed in brackets, refer to paths or portion of paths, indicated by dotted lines. The earthquakes are indicated by numbers (see B.A. Reports



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take the other theory, although there are difficulties of detail that are somewhat troublesome. I do not think we are in a position as yet to make any serious calculations. We must get more data and look all round them before engaging in complicated calculations.

Character of path in three cases on the assumption that the path is not along the chord, but more approximately along the arc.

Alaskan.

Victoria	Under sea.
Toronto	Half sea, half land.
Mexico	Half sea, half land.
Shide	Mostly sea, polar archipelago, Greenland ?
San Fernando	Half sea and land, largely polar.
Bombay	Mostly land, Siberia, Tibet.
Batavia	Deep sea, east of Asia.
Mauritius	Siberia, India, Indian Ocean.
Cape of Good Hope	Polar sea, Europe, Africa.

Mexico.

Victoria	Under N. America.
Toronto	" "
Shide	Skirting E. of N. America and then under Atlantic.
Batavia	N. America, Pole, Asia.
Mauritius	N. America, Pole, Russia, Persia, Indian Ocean, or by way of S. Pole.

Ceram.

Batavia	East India Archipelago.
Mauritius	Indian Ocean.
Victoria	Pacific Ocean.
Cape of Good Hope	Indian Ocean.
Shide	India, Persia, Europe.

Alaskan Earthquakes (333, 327, 338).

Assuming constant speed for small distances, we find 9 min. as the time from the origin to Victoria. Hence the following table :—

Arc		Chord	Time of Passage in Min.			Speed		
						Arc Degrees / Min.	Chord / Min.	Arc Radians / Min.
Victoria	16°	·28	9	—	—	1·8	·031	·031
Toronto	40	·68	22	22	22	1·8	·31	·31
Mexico	49	·83	—	29	28	1·7	·29	·30
Shide	70	1·15	39	42	41	1·8	·29	·31
San Fernando	77	1·25	44	44	44	1·75	·28	·305
Bombay	105	1·59	55	55	57	1·9	·28	·33
Batavia	108	1·62	—	65	75	{1·66 / 1·44}	·23	—
Mauritius	145	1·91	90	—	88	1·63	·215	·284
Cape of Good Hope	165	1·98	88	89	83	1·9	·226	·33

Mexico (250, 381).

Assuming 21, 22 mins. as times from origins to Victoria :

Arc		Chord	Time in Min.	$\frac{\text{Arc Degrees}}{\text{Min.}}$	$\frac{\text{Chord}}{\text{Min.}}$
Victoria . .	30–32	·52–·55	21–22	1·4	·025
Toronto . .	34–36	·58–·62	23–27	1·4	·25
Shide . . .	80–83	1·29–1·33	52–54	1·52	·25
Batavia . .	150	1·93	108	1·39	·18
Mauritius . .	160	1·97	113	1·41	·175

Ceram (347).

Time calculated as in Alaskan earthquake.

Arc		Chord	Time	$\frac{\text{Arc Degrees}}{\text{Min.}}$	$\frac{\text{Chord}}{\text{Min.}}$
	°		Min.		
Batavia . . .	22	·38	14	1·57	·027
Mauritius . .	73	1·19	47	1·55	·25
Victoria . . .	105	1·59	74	1·42	·22
Cape of Good Hope.	105	1·59	61	1·72	·26
Shide . . .	121	1·74	71	1·71	·246

$\frac{\text{chord}}{\text{min.}}$ and $\frac{\text{arc radians}}{\text{min.}}$ may be reduced to $\frac{\text{kilom.}}{\text{sec.}}$ by multiplying by 1·06

$\frac{\text{arc degrees}}{\text{min.}}$ " " " " " " " " 1·84

It will be noted that there are certain slight differences between the figures used in this last table and those in the table on p. 81. These, however, do not produce any appreciable effect upon the general character of the investigations which have been made.

13. *The Origin of Large Earthquakes which were recorded in the Isle of Wight in the Year* 1899.

In 1899, at Shide, in the Isle of Wight, 130 earthquakes were recorded. One hundred and five of these were also recorded at one or more of the following places: Kew, Toronto, Victoria (B.C.), San Fernando, Bombay, Madras, Calcutta, Mauritius, Batavia, Cape of Good Hope, Tokio, Cairo, and Mexico. There is no doubt that many of these were also recorded at other observatories, but from these registers have not yet been received.

The localities at which a certain number of these earthquakes originated have been determined with a fair amount of accuracy. Other determinations are somewhat indefinite, whilst a large residuum of comparatively small disturbances have been grouped as having originated somewhere in the vicinity of the one or two stations at which they were recorded.

The results exhibited in map (Plate III.) are therefore of varying values, and although they give a general idea as to the distribution of seismic activity for 1899, they are chiefly of interest as illustrating the character of the more definite information which we may expect to derive from the extension of the present system of observation.

The methods and considerations which have led to these determinations have been as follows :

(1). *Determination of Origins by Comparisons between Time Intervals.*

Earthquakes from the same district will arrive at distant observing stations at times the differences between which will be constant. If, for example, we have once determined the difference in time at which an earthquake originating off the coast of Japan arrives at Batavia, Bombay, Cape of Good Hope, Shide, &c., whenever these differences are repeated at four or more stations, without knowing anything about observations in Japan, we can at once say where such an earthquake has originated. It will be noted that our knowledge respecting the speed with which earthquake motion is transmitted enables us to give approximate values for the time differences here considered.

(2). *By the Difference in the Times at which the Maximum Motion has been recorded at different Stations.*

In the present state of our knowledge all determinations of the position of origins from time intervals require the assumption that the velocity of propagation of earthquake movement is constant. This condition is most nearly fulfilled by the large waves of earthquakes. The methods by which an earthquake origin may be determined from the differences between the times at which it was recorded at distant stations are several. The method of circles which is here employed has been selected chiefly on account of its comparative simplicity in application. It is briefly as follows : If the large waves of an earthquake reach stations B, C, D, &c., four, ten, twenty, &c., minutes after reaching station A, then the centre of a circle which passes through A and touches circles drawn round B, C, D, &c., the radii of which are respectively $4 \times 1^\circ{\cdot}6$, $10 \times 1^\circ{\cdot}6$, $20 \times 1^\circ{\cdot}6$, &c., will be the centre of the origin required. The constant $1^\circ{\cdot}6$ means that the arcual velocity for large waves is taken at $1^\circ{\cdot}6$ per minute, or approximately 3 km. per second. In the British Association Report for 1899, p. 193, the speed there given was 2·5 km. per second, which appears to be too low. The operation of drawing these circles is carried out on a 'slate' globe. For a complete solution observations are required from at least four stations. With only three observations we are left to choose between two possible centres, but as these may be widely separated there is usually but little difficulty in selecting the one required.

(3). *By the Time Intervals between the Arrival of Preliminary Tremors and Maximum Movement.*

From what has been said respecting preliminary tremors and large waves it may be inferred that the interval in time between the appearance of these two phases of earthquake motion at a given station has a relation to the distance of that station from the origin. This relationship is shown in fig. 1. An observer with this curve before him, although his timekeeper may have failed, or although he may be so situated that it is impossible to obtain accurate time, is immediately able to determine from a well-defined seismogram the distance at which the motion it represents originated. With this fact, the magnitude of his record, and a knowledge of the physical configuration of districts from which earthquakes originate, he is frequently able to locate an origin. With time records from several

stations the distances corresponding to each of them from an origin are read from the curve, and by the intersection of these on a globe seismic foci are determined with greater certainty.

(4). *By the Intervals represented by Seismic Recurrences.*

Whenever a seismogram shows the interval of time between a maximum movement and a distinct reinforcement of vibrations which cannot be accounted for as forming part of the gradually decreasing surgings following the principal disturbance, this interval enables us to state the distance of the origin from the station at which the seismogram was obtained. Opportunities to apply this method are not frequent (see p. 68).

14. *The Application of the above Methods to the Records for* 1899.

To carry into effect the method of determining origins by comparisons of time differences, the following eleven tables have been prepared. In these the 105 Shide records are referred to by their British Association register number and their date. For each of these the time intervals between the arrival of maximum motion at the station beneath which a zero is placed and its arrival at other stations are given in minutes. In those instances where the time at which an earthquake originated is approximately known, as in Table I., the zero is placed beneath the word 'origin.' So far as possible the various earthquakes have been analysed according to the localities from which they originated. When the time intervals in a series are less than three in number, the location of an origin is sometimes doubtful. A dash beneath a station indicates that an earthquake was observed, but for reasons which are various the time of its maximum could not be determined. A query indicates that an observation is uncertain.

TABLE I. *West Pacific. Japan.*

—	Shide	Kew	Toronto	Victoria, B.C.	San Fernando	Bombay	Batavia	Mauritius	Madras	Calcutta	Cape of Good Hope	Cairo	Origin
Distance in degrees	87	87	90	62	100	65	57	102	62	52	136	87	0
Expected time to travel in mins.	57	57	59	38	65	43	35	66	38	35	85	57	0
366. Nov. 24	57	58	—	32	68	37	14	51	37	—	68	60	Japan
364. Nov. 23	—	20?	58	32	64	40	31	54	54	—	{ 54 or 85 }	—	„
360. Nov. 18	46	—	—	—	—	—	—	—	—	—	—	—	„
357. Nov. 10	50	—	—	—	—	—	—	—	—	—	—	—	„
311. July 17	—	—	—	—	—	—	19	—	—	—	—	—	„
307. July 11	17 ?	—	17	39 ?	—	—	17	21	—	—	—	—	„
306. July 10	53	—	—	—	—	48	—	—	—	—	—	—	„
295. June 17	—	—	58	—	—	67?	—	—	—	—	—	—	Philippines ?
263. March 7	58	58	68	23	—	47	17	42	—	—	—	—	Japan
323. Aug. 3	57	—	20	21	—	—	—	—	—	—	—	—	„

The above earthquakes were recorded by seismographs in Japan, and therefore originated in or near that country.

In very many of these entries there must be errors, the reasons for the existence of which have already been explained. The values of these vary between a fraction of a minute and several minutes.

Where origins are known from observations made near to the same these are stated.

The geographical positions of these origins are shown in map (Plate II.). Some of the entries on this, particularly those for the Atlantic and Indian Ocean, are conjectural, whilst others may be taken as correct. The reliance which can be placed upon any particular determination is shown in the table of time intervals on which the same is founded.

263. This earthquake, which is described in the British Association Report, 1899, p. 212, and was recorded in Tokio at 0h. 59m. 29s. G.M.T. March 7, is of interest as showing that the amplitudes of motion recorded at Shide and Kew were greater than those recorded at Toronto, whilst at Victoria, the nearest station to the origin, but reached by a sub-oceanic path, it was the smallest of all (see p. 70).

Other earthquakes, approximately corresponding to entries in the Tokio register, and which may therefore have originated near to Japan, are Nos. 271, 286, 314, and 363. Nos. 351 and 352 may have originated to the east of Japan, about 40° N. lat. and 160° E. long.

TABLE II. *West Equatorial Pacific. East Indies.*

—	Shide	Kew	Toronto	Victoria (B.C.)	San Fernando	Bombay	Batavia	Mauritius	Madras	Calcutta	Cape of Good Hope	Tokio	Remarks
Distance in degrees	121	121	136	105	132	62	22	73	53	50	105	47	These entries relate to the origin.
Expected time intervals	76	76	85	66	84	38	16	45	33	32	66	29	
347. Sept. 29	70 or 57	70 or57	—	73 or 60	30 or 17	28 or15	0	40 or33	—	18 or 5	60 or47	18 or 5	According as the Batavian max. is 17·11 or 17·24
247. Jan. 12 .	63	—	—	—	—	?	0	—	—	—	—	—	—
298. June 24 .	57	—	56	71	—	13	0	15	—	—	—	—	—
299. June 29 .	60	—	—	71	—	7	0	—	9	—	—	—	—
310. July 17 .	63	—	35 ?	48	—	—	0	—	—	—	—	—	—
324. Aug. 4 .	55	26	21 or41	18 or58	32	13	0	42	11	12	58	—	—
332. Aug. 24 .	71	70	52	35	13	—	0	49	—	—	59	—	—
354. Oct. 19	64 or 68	—	—	56 or 52	—	—	0	40 or36	—	—	50 or46	5	—
355. Oct. 24 .	61	—	91	61	—	—	0	35	—	—	46	—	—

347. Dr. J. P. van der Stok in the 'Kon. Akad. van Wettenschappen te Amsterdam,' Nov. 25, 1899, tells us that in the night of September 29–30, at 1.45 A.M. (September 29, 17h. 9m. G.M.T.), an earthquake, followed by sea waves, damaged the south coast of Ceram, and, in less degree, the islands of Ambou, Banda, and the Ulias Isles. Several villages on the south coast of Ceram were destroyed—in Elpapoeti Bay all except two. The prison at Amahei was completely destroyed, and the fortifications partly so.

Dr. R. D. M. Verbeek gives an account of this earthquake in the

'Javasche Courant,' 1900, No. 21. He gives Amahei time for the shock as 1h. 42·2m., and that for Wahei as ± 1h. 43m. (17h. 7m. G.M.T.). At the former place five to ten minutes after the shock, the coast was flooded by a sea wave. This inundation, to a height of 1·7 to 9 metres, was also experienced at other places along the south coast of Ceram. At Banda, 187 km. south-east from Elpapoeti Bay, the water began to rise about half an hour after the shock. At Kawa, at the west end of Ceram, and at other places, strips of alluvium were submerged. Dr. Verbeek places the centrum a few miles inland to the west of Elpapoeti Bay, on the line of a fault running parallel to the south coast of Ceram.

The time intervals between the shock and the sea wave observed at Amahei indicate an origin at a distance of ·5 to 1 degree from that place. This would probably be sub-oceanic, and on the face of the Webber Deep, where soundings have been obtained of 4,000 fathoms. As it is possible that there may have been a bodily displacement of materials lying between Ceram and the Webber Deep, this does not interfere with Dr. Verbeek's fault line. The time at the origin may therefore be taken as lying between 17h. 7m. and 17h. 9m. If the maximum observed at Batavia took place at 17h. 24m., and the movement took 15 minutes to reach that place, we again reach the conclusion that the time at the origin was about 17h. 9m. G.M.T.

TABLE III. *Mid-Indian Ocean.*

—	Shide	Toronto	Batavia	Madras
288. May 15	56	—	0	61
313. July 20	42?	39	0	—
319. July 29.	45	—	0	—

TABLE IV. *North-east Pacific. West of Alaska.*

—	Shide	Kew	Toronto	Victoria, B.C.	San Fernando	Bombay	Batavia	Mauritius	Madras	Calcutta	Cape of Good Hope	Mexico	Tokio	Remarks
Distance in degrees	70	70	40	20	77	100	108	145	105	90	165	49	50	These entries refer to the origin.
Expected time intervals	44	44	25	14	48	63	68	92	67	57	104	31	32	
333. Sept. 3 . .	30	30	{13 28?}	0	36	47	—	81	—	—	{100, 89 79}	—	{17 16}	
337. Sept. 10 . .	20	20	0	—	22	34or33	50or43	—	39or38	—	69or67	7	—	Small
338. Sept. 10 . .	20	19	0	—	22	35	53	64	—	—	61	6	—	—
246. Jan. 12 . .	23	—	13	0	—	?	—	—	—	—	—	—	—	—
266. March 19 .	30	—	9	0	—	—	—	—	—	21	—	—	—	—
282. April 16 . .	31	39	15	0	—	—	—	94	—	—	—	—	—	—
334. Sept. 4 . .	—	—	9	0	36	—	—	—	—	—	—	—	—	—
341. Sept. 16 . .	16	18	0	—	21	—	—	—	—	—	64	—	—	—
342. Sept. 17 . .	27	27	10	0	34	47	—	—	48	—	76	—	—	—
344. Sept. 23 . .	25	31	11	0	35	50	60	77?	—	—	72	—	27	—
345. Sept. 23 . .	33	37	17	0	38	63	—	—	—	—	87	—	—	—
309. July 14 . .	11	11	9	0	14	13	—	14?	—	—	35	—	—	Behring Sea
317. July 27 . .	11	—	6	0	—	—	—	—	—	—	—	—	—	—

Nos. 333, 337, and 338. In the 'Toronto World' of September 25 we read that on September 3, about 2.30 P.M., houses in Yakuta Bay were rocked violently, doors were slammed, dishes rattled, and tables moved. On September 10, about eight o'clock, a more violent movement occurred. Trees swayed, and there were slight shakes every few minutes. Just as the earthquake ceased tidal waves came rolling in. There were three of these waves following each other at intervals of about five minutes. The rise was 15 feet from low tide to a foot above the highest tide point. On the island of Kanak, opposite Yakuta, a graveyard sank so that on the next day a boat was able to row over the place where it had been, and the tops of the submerged trees could be seen.

These shocks disturbed the declinometer, duplex, and vertical force magnetographs in Toronto.

Scanty as these notes are, they apparently indicate an origin somewhat to the east of that shown in Plate III.

The period of the earth waves for No. 333 as recorded at Shide was 15 seconds, whilst the maximum angle of tilting was $8''$. With a velocity of 3 km. per second, and the assumption that the motion is simple harmonic, so that the height of the waves$=\frac{l}{2\pi}\tan a$, where l=length of wave and a=maximum angle of tilting, we may conclude that these waves were 45 km. in length and 29 cm. in height. With periods of at first 40 and afterwards 15 seconds for the disturbance recorded in the Isle of Wight on September 10, No. 338, it would appear that at first there were waves 120 km. long and 39 cm. high, followed by others 45 km. long and 43 cm. high. Whether we can accept vertical displacements of this order representing accelerations not unfrequently $\frac{1}{50}$ of gravity is yet *sub judice*, and an experiment to confirm or modify these conclusions is now in progress.

TABLE V. *East Mid-Pacific. West of Mexico.*

—	Shide	Kew	Toronto	Victoria, B.C.	San Fernando	Bombay	Batavia	Mauritius	Madras	Calcutta	Cape of Good Hope	Origin
Distance in degrees	84	84	34	30	86	148	150	168	148	138	138	0
Expected time intervals	52	52	22	20	54	93	95	105	93	87	87	0
250. Jan. 24 .	31	31	3	0	—	—	—	92	—	—	—	Mexico
381. Jan. 20 .	—	32	2	0	—	—	86	—	—	—	—	"
248. Jan. 14 .	37	{31 or 35}	2	0	—	—	—	—	—	—	—	"
321. Aug. 2 .	30	30	0	—	—	—	—	—	—	—	—	Concepcion ?
294? June 14 .	32	30	0	34	16	70	—	72	—	—	—	Jamaica ?
371. Dec. 25 .	47	47	16	9	60	—	—	—	—	—	75	S. California

250. The key to the origin of this group is given by earthquake No. 250. From Señor José Zandizas, director of the observatory in Mexico, we learn that it took place on January 24, 1889, at approximately 11h. 45.5m. P.M. It was severe, caused some damage, but it cannot be siad

to have been very strong. It was felt over the whole republic. At Colima, on the Pacific side, it had a duration of 1m. 20s., and on the Atlantic side, at Vera Cruz, it lasted 10s.

By the method of circles and by the method of preliminary tremor intervals I place the origin at a point 30° distant from Victoria, and 34° from Toronto, or near to lat. 19° N. and 105° W. long. On January 20, 1900, No. 381 was recorded in Mexico with time intervals similar to those for No. 250. The preliminary tremor intervals for this referring to Victoria, Toronto, and Kew read 13, 15, and 38 minutes, indicating that the Kew reading for No. 250 is the lower of the two values given.

The time readings for 248 clearly correspond with that for an earthquake with a similar origin.

294. An origin S.W. of Jamaica roughly agrees with the time differences between Toronto, Victoria, and Shide, and the preliminary tremors duration for Kew and Toronto.

371. In 'Nature,' April 19, 1900, we read that on December 25, at 12.25, an earthquake took place in S. California. In the villages of San Jacinto and Hermet every brick building was damaged.

Professor F. Stupart sends me the following extract from a newspaper clipping:

Los Angeles, Cal., December 25, 1899.

The towns of San Jacinto and Hernet, in Riverside County, were badly shaken by an earthquake at 4.25 o'clock this morning. In San Jacinto not a brick house or block escaped injury. Nearly all of the business portion is in ruins. The new Southern California Hospital caved in. It was not occupied. At Hernet the Hernet's Company mill is partly down. The front wall fell flat. The rear of the large Johnston block also toppled over. Hernet's new hotel is a ruin. The damage at those places cannot be estimated now. Communication by wire is interrupted. The 'Herald' has received a telegram from San Bernardino saying that six Indians were killed at Hernet by falling walls during the earthquake. The Santa Fé railroad report is to the effect that no lives were lost.

Los Angeles, December 25.—The total damage at San Jacinto and Hernet is estimated at $50,000. No person was injured at either place so far as known. The shock was heavy at Santa Ana, Anheim, San Bernardino, Riverside, and other places, but no particular damage is reported except from San Jacinto and Hernet. In this city no damage was done, though the shock was particularly violent. The houses here are well filled with Eastern tourists, and they were in many instances terrified at the unexpected disturbances, and rushed from their rooms.

San Diego, Cal., December 25.—The most severe shock of earthquake experienced in this city in fourteen years took place at 4.25 A.M. to-day, and was accompanied by a loud rumbling noise. The taller buildings in this city were severely shaken, but no serious damage was done. A high wave struck the beach ocean front, but no damage was done. A slight shock followed the first a few seconds later.

268. The time intervals for Shide, Victoria, Bombay, and Toronto suggest an origin near to that given for 322, with which the preliminary tremors for Victoria and Mauritius accord. In the British Association Report for 1899 this origin was placed on the western side of the Atlantic, but additional data having since been obtained this is now modified.

TABLE VI. *South-East Pacific. West Coast South America.*

	Shide	Kew	Toronto	Victoria, B.C.	San Fernando	Bombay	Batavia	Mauritius	Madras	Calcutta	Origin
322. Aug. 2 .	25	23	0	—	—	—	—	—	—	—	Concepcion.
321. ,, 2 .	30	30	0	—	—	—	—	—	—	—	Chili ? See W. of Mexico, list V.
268. Mar. 23 .	10	14	0	11	?	41	—	23	—	—	S.E. Pacific.
269. ,, 23 .	22	29	0 ?	20	—	—	—	—	—	?	—
270. ,, 25 .	35 or 8	?	0	14	?	—	—	—	—	—	—
278. April 12 .	26	36	0	20	—	—	—	—	43	—	W. of Chili
279. ,, 13 .	21	31	0	14	—	—	—	—	44	—	—
291. June 5 .	33 ?	0	0	15	—	—	11	—	—	—	—
292. ,, 5 .	23	30	0	15	—	—	—	—	—	—	—

322. The time intervals indicate a possible origin, about 80° due south from Toronto, or off the south coast of South America, near Concepcion. As this earthquake is not a large one, the whole of the preliminary tremors have not been recorded, and therefore these indications may be neglected.

The similarity of the seismograms for this earthquake and that for 321, together with the fact that they succeeded each other within two hours, suggest a similar origin, and Professor F. Stupart, of Toronto, writes me to the effect that it is probable that both originated off the South American coast.

TABLE VII. *North Atlantic. North Norway to Spitzbergen.*

	Shide	Kew	Toronto	Victoria, B.C.	San Fernando	Bombay	Batavia	Mauritius	Madras	Calcutta	Cape of Good Hope	Tokio	Origin
252. Jan. 31	0	0	12	16	—	?	—	—	—	—	—	—	—
254. Feb. 23	0	?	15	19	—	—	—	—	—	—	—	—	—
255. ,, 26	0	?	—	20	—	—	—	—	—	—	—	—	—

TABLE VIII. *Equatorial Atlantic.*

308. July 12	0	10	8	40	2	36	—	23	34	—	—	—	—

TABLE IX. *Western Central Asia. Turkey in Asia.*

343. Sept. 20	0	2	33	40	10	14	—	34	—	—	29	30	Smyrna
373. Dec. 31	4	0	31	40	5	—	—	14	—	—	26	−6	Tiflis

343. From 'Nature,' January 25, 1900, we learn that more than 1,600 persons were killed, more than 2,000 were injured, whilst 11,000 houses were destroyed. The epicentre was in the Meander Valley, between Aidin and Sarakim. Along a line of sixty miles in this valley there are many

damaged towns and villages. This valley and the Legens Valley have subsided from 2 to 6 feet. The railway line between Aidin and Omourlou was raised fully one yard.

373. From 'Nature,' January 25, 1900, we learn that the earthquakes of December 31 destroyed many houses at Akhalkalaki (Transcaucasia). Here and in ten neighbouring villages over 200 people perished. At the Tiflis Physical Observatory the following observations were made. In Greenwich mean time the first shock was at 10h. 51·4m. It was severe in the hilly part of the city, on the right bank of the river Kura. The second shock was feeble and noted at 13h. 39·5m. The third shock was not noted by the seismograph at the observatory on the left bank of the Kura, but was noted at 17h. 45m. on the right bank. At Kalagelan the first was observed at 10h. 49m., and at Sviri and Zugdidi at 11h. 23m. The latter places are on the Kars Railway. At the railway stations, Abastuman and Kobi, the times were 13h. 51m. and 11h. 2m.

TABLE X. *Origins which are extremely doubtful.*

B. A. No.	Shide	Kew	Toronto	Victoria, B.C.	San Fernando	Bombay	Batavia	Mauritius	Madras	Calcutta	Cape of Good Hope	Origin
245. Jan. 6 .	6	?	0	—	?	?	—	—	—	—	—	N. Atlantic, W. side.
249. ,, 22 .	4	0	—	—	—	?	—	—	—	—	—	Greece ?
251. ,, 30 .	64	?	—	?	—	4	—	—	0	—	—	Indian Ocean, E. side.
253. ,, 31 .	16	15	—	—	—	0	—	—	—	—	—	,, ,, W. side.
256. Feb. 27 .	?	?	0	5·7	?	?	—	—	—	—	—	W. Indies.
257. ,, 27 .	0	0·5	—	—	—	—	—	—	—	—	—	N. Atlantic, E. side.
259. ,, 28 .	0	0	13	?	?	?	—	—	—	—	—	N. Atlantic, C. Verde.
260. ,, 28 .	0	—	—	—	—	—	—	—	—	—	—	Trieste 13 min. after Shide, N. Atlantic, W. side.
262. Mar. 6 .	22	?	—	—	—	—	—	—	—	—	—	Nicolaiew, before Shide, Caspian Sea.
264. ,, 12 .	28	?	0	1	—	?	14?	?	—	?	—	Origin, S. Pacific. The magnitude of the seismograms indicates that Toronto was reached before Shide and Victoria. The maximum was not well defined at Victoria, whilst at Batavia the movements were only recorded as a thickening of the line. The position of the origin was apparently in the Mid-South Pacific.
267. ,, 21 .	16	?	—	—	?	—	—	—	—	?	—	Trieste, before Shide, Caspian Sea.
273. April 4 .	0	—	—	—	—	—	—	—	?	—	—	N. Atlantic, E. side.
276. ,, 6 .	1	0	—	—	—	—	—	—	—	—	—	,, ,,
281. ,, 15 .	—	—	—	—	—	—	—	—	—	—	—	,, ,,
283. ,, 17 .	43	—	34	0	—	—	—	—	—	—	—	N.E. Pacific.
284. ,, 28 .	—	—	—	—	—	—	—	—	—	—	—	N. Atlantic, E. side.
289. May 17 .	19	—	—	—	—	—	0	—	—	—	—	Indian Ocean ?
293. June 9 .	1	—	—	—	—	—	—	0	—	—	—	,, ,,
297. ,, 19 .	—	—	—	—	—	—	—	—	—	—	—	N. Atlantic, E. side.
300. July 2 .	—	—	—	—	—	—	—	—	—	—	—	,, ,,
301. ,, 2 .	30	—	—	0	—	?	—	—	—	—	—	E. Pacific Ocean.
302. ,, 3 .	—	—	—	—	—	—	—	—	—	—	—	N. Atlantic, E. side.
303. ,, 7 .	9	1	0	4	—	—	21	—	—	—	—	N. Atlantic, W. side.
305. ,, 9 .	46	50	86	75	—	6	—	—	0	—	—	Equatorial Indian Ocean.
312. ,, 10 .	?	—	—	—	?	—	—	—	—	—	—	N. Atlantic, E. side.
315. ,, 26 .	4	—	—	—	—	0	—	—	—	—	—	Indian Ocean.
318. ,, 28 .	—	—	—	—	—	—	—	—	—	—	—	N. Atlantic, E. side.
220. ,, 31 .	—	—	—	—	—	—	—	—	—	—	—	Indian Ocean ?
325. Aug. 7 .	9	9	—	—	—	0	—	—	—	0	—	,, ,,
326. ,, 17 .	?	?	36	17	24	0	—	19	3	—	28	Eastern East Indies.
327. ,, 21 .	?	?	—	—	—	—	—	—	—	—	—	N. Atlantic, E. side.
328. ,, 23 .	?	?	—	—	—	—	—	—	—	—	—	,, ,,
329. ,, 23 .	?	?	—	—	—	—	—	—	—	—	—	—

TABLE X. *Origins which are extremely doubtful*—continued.

B. A. No.	Shide	Kew	Toronto	Victoria, B.C.	San Fernando	Bombay	Batavia	Mauritius	Madras	Calcutta	Cape of Good Hope	Origin
335. Sept. 6 .	29	—	0	—	—	—	—	—	—	—	—	W. of Mexico. Group V.
336. „ 6 .	0	—	1	—	—	—	—	?	—	—	—	Mid N. Atlantic.
340. „ 14 .	11	—	0	—	—	—	—	—	—	—	—	N. Atlantic, W. side.
346. „ 27 .	6	6	0	15	—	—	—	—	—	—	7	Mid-Equatorial Atlantic ?
349. Oct. 4 .	—	—	—	—	—	—	—	—	—	—	—	N. Atlantic, E. side.
351. „ 13 .	36	—	31	7	—	—	0	—	—	—	2	—
352. „ 13 .	33	38	—	9	—	—	0	—	—	—	63	E. of East Indies ?
356. „ 29 .	0	—	—	—	—	—	5	—	—	—	—	Indian Ocean.
358. Nov. 12 .	11	—	—	27	—	—	0	—	—	—	49	S. Pacific.
361. „ 18 .	25	2	0	23	3	—	—	—	—	—	3	Mid-Equatorial Atlantic.
362. „ 20 .	42	—	33	0	4	—	—	—	—	—	—	Pacific Ocean.
365. „ 24 .	58	—	—	50	63	20	0	38	—	—	9?	Japan ?
370. Dec. 17 .	—	—	—	—	—	—	—	—	—	—	—	N. Atlantic, E. side.
372. „ 26 .	27	7?	1	18	0	—	—	—	—	—	35	—
374. „ 31 .	51?	25	41	34	33	0	10	—	—	—	48	Japan ?

The origins indicated in the last table are for the most part conjectural. In those instances where a disturbance has only been recorded at Shide and Kew, and we are without evidence showing that the seismograms refer to earthquakes observed in Great Britain and Europe, it seems probable that they represent adjustments in the strata on the eastern side of the North Atlantic. Time entries for these stations, a few minutes later than the corresponding entry for Toronto, suggest that we are here dealing with a disturbance originating on the western side of the same ocean.

Origins indicated by terms like Indian Ocean and Pacific Ocean only show how little information can be derived from certain seismograms.

Here and there a few impossible entries are recorded. For example, the greatest interval of time which could elapse between the arrival of an earthquake in Mauritius and Bombay or Madras is thirty minutes, yet for earthquake 326 it will be observed that the entries for the latter places are respectively forty-one and forty-five minutes. To correct such entries it is necessary to compare together the original seismograms, which has not been always possible.

15. *Illustrations of Seismograms.*

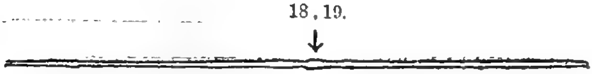
The following illustrations of seismograms are only to be regarded as *sketches* of the original photograms. The accuracy of any given reproduction has been largely dependent upon the clearness of the figure from which it was copied. They show the range of motion and the principal characteristics of wave-groups, but they do not show details like small serrations so clearly exhibited in many of the original records from which they have been reproduced. The numbers correspond with the numbers given for particular earthquakes in the preceding text and those in the Shide records contained in the first circular of earthquake registers issued by the Seismological Investigation Committee. The arrow with its time-mark gives the time for a particular phase of movement, which is usually that of the commencement. The number following the letter S gives the time-scale in millimetres per hour. Thus S=60 means that 60 millimetres equal one hour.

The locality at which a seismogram was obtained is indicated by the following initial or initials :—

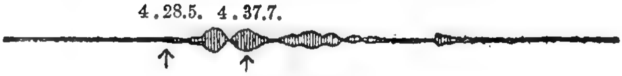
Isle of Wight (Shide)	S.	Bombay	B.
Kew	K.	Calcutta	C.
Toronto	T.	Batavia	Ba.
Victoria, B.C.	V.	Mauritius	M.
San Fernando	S.F.	Cape of Good Hope	C.G.H.
Madras	Ma.	Tokio	To.
Mexico	Me.		

No. 278.—S. S=58.

No. 278.—T. S=59·5.

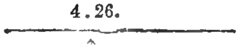


No. 278.—V. S=60·5.



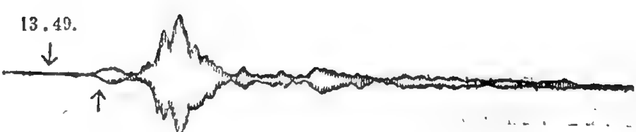
No. 279.—S.

No. 279.—T. S=59·5.

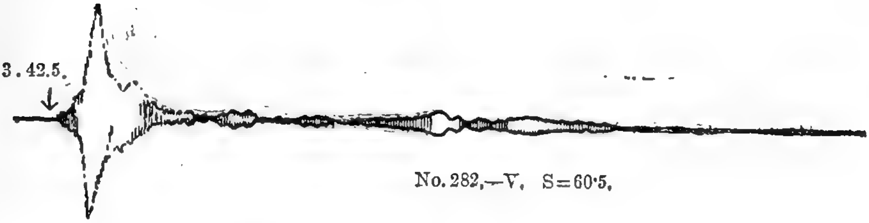


No. 279.—V. S=61.

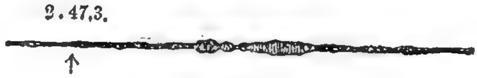
No. 282.—S. S=58.



No. 282—T. S=59.



No. 282.—V. S=60·5.

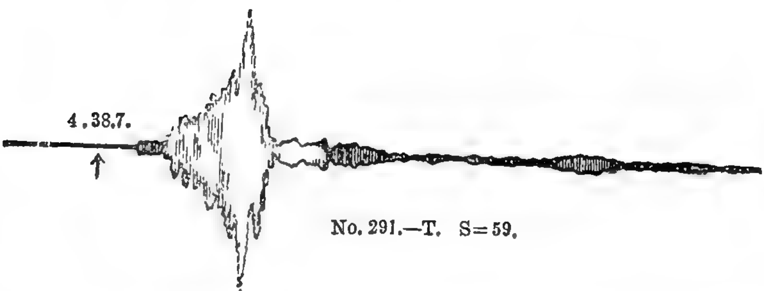


No. 283.—S. S=58.

No. 283.—T. S=59.

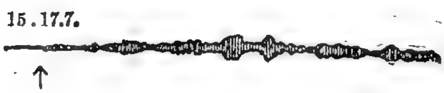
No. 283.—V. S=60·5.

No. 291.—S. S=58.



No. 291.—T. S=59.

No. 291.—V. S=60·5.



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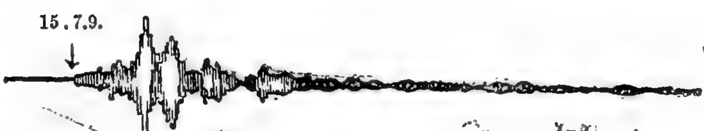
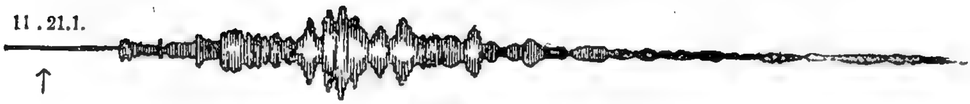


No 292.—T. S=52.

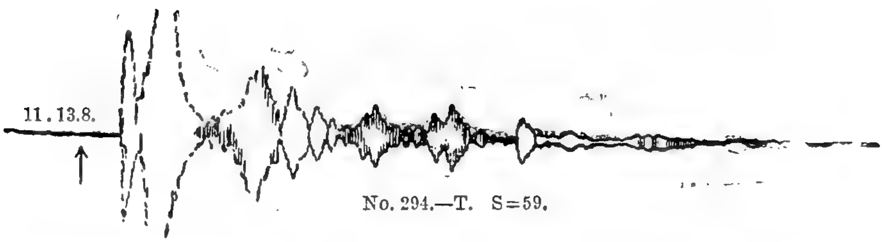
No. 292.—V. S=60·5.

No. 294.—M. S=58.



No. 294.—S. S=58.

No. 294.—S.F.



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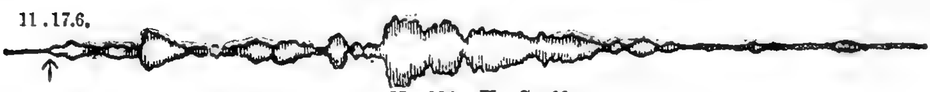

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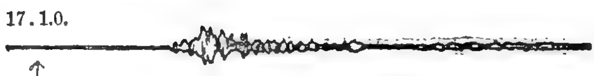
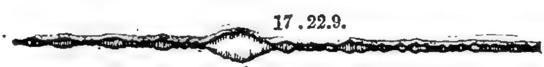


No. 298.—Ba. S=60.



No. 298.—M. S=58.

No. 298.—S. S=58.

Repetition

13.36.6.

No. 309.—S. S=58.

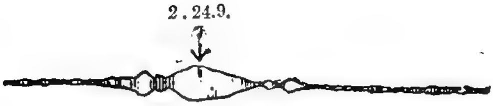
No. 305.—B. S=60.

19.27.5.

No. 305.—S. S=58.

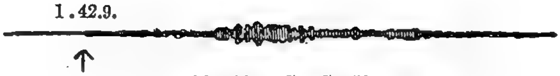
No. 308.—B. S=59.

2.24.9.



No. 308.—M. S=58·5.

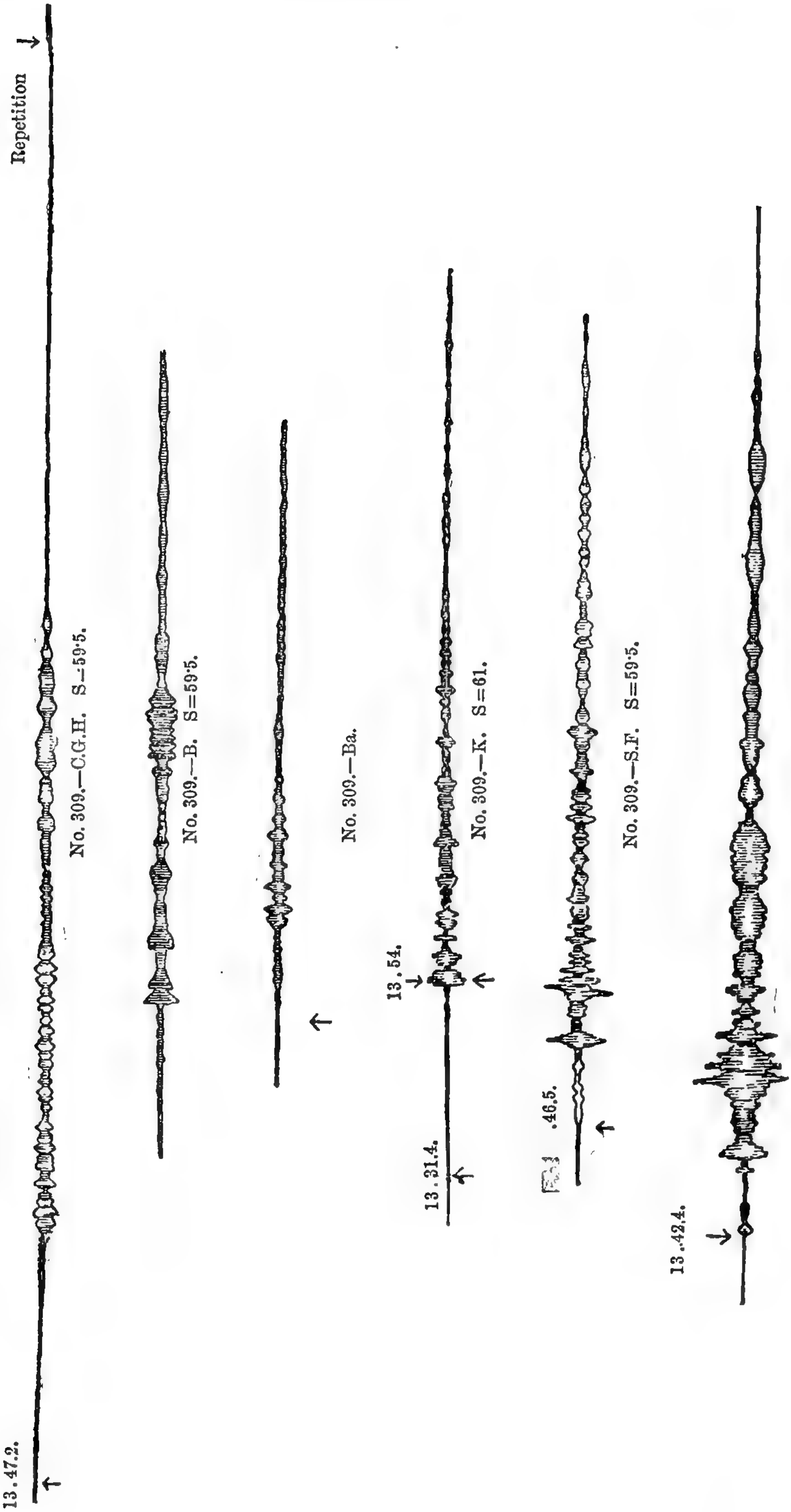
1.42.9.

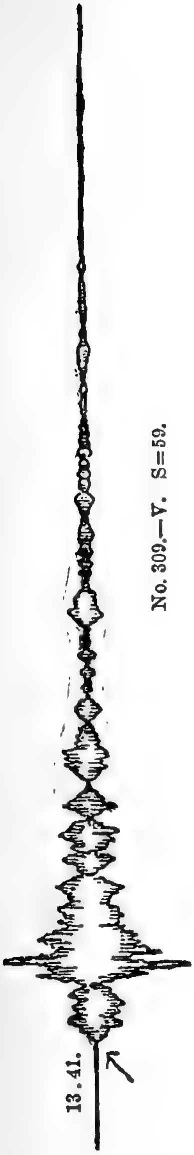


No. 308.—S. S=58.

1.41.2. 2.3.7.

No. 308.—S.F.


Repetition
No. 309.—C.G.H. S.–59·5.
13.47.2.
No. 309.—B. S=59·5.
No. 309.—Ba.
No. 309.—K. S=61.
13.54.
13.31.4.
No. 309.—S.F. S=59·5.
.46.5.
No. 309.—T. S=59.
13.42.4.



13.41.

No. 309.—V. S=59.

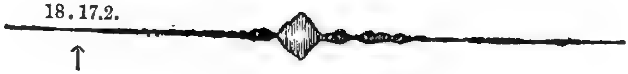
14.50.2.

No. 321. S=58.

15.27.9.

No. 321.—T. S=58·5.

18.17.2.



No. 322.—S. S=58.

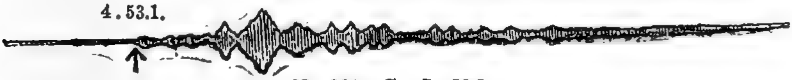
18.4.6'

No. 322.—T. S=58·5.

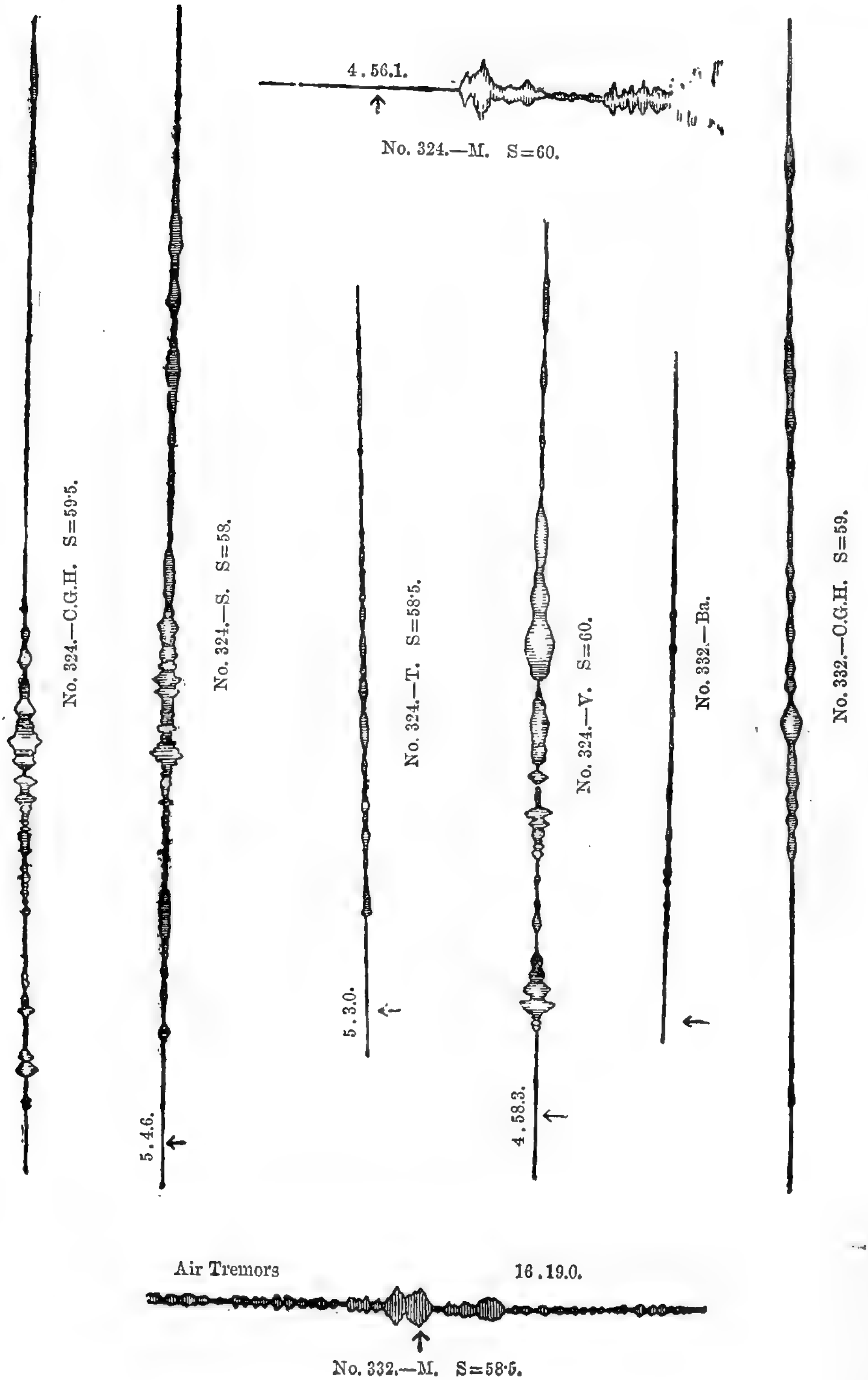
No. 324.—B. S=59.

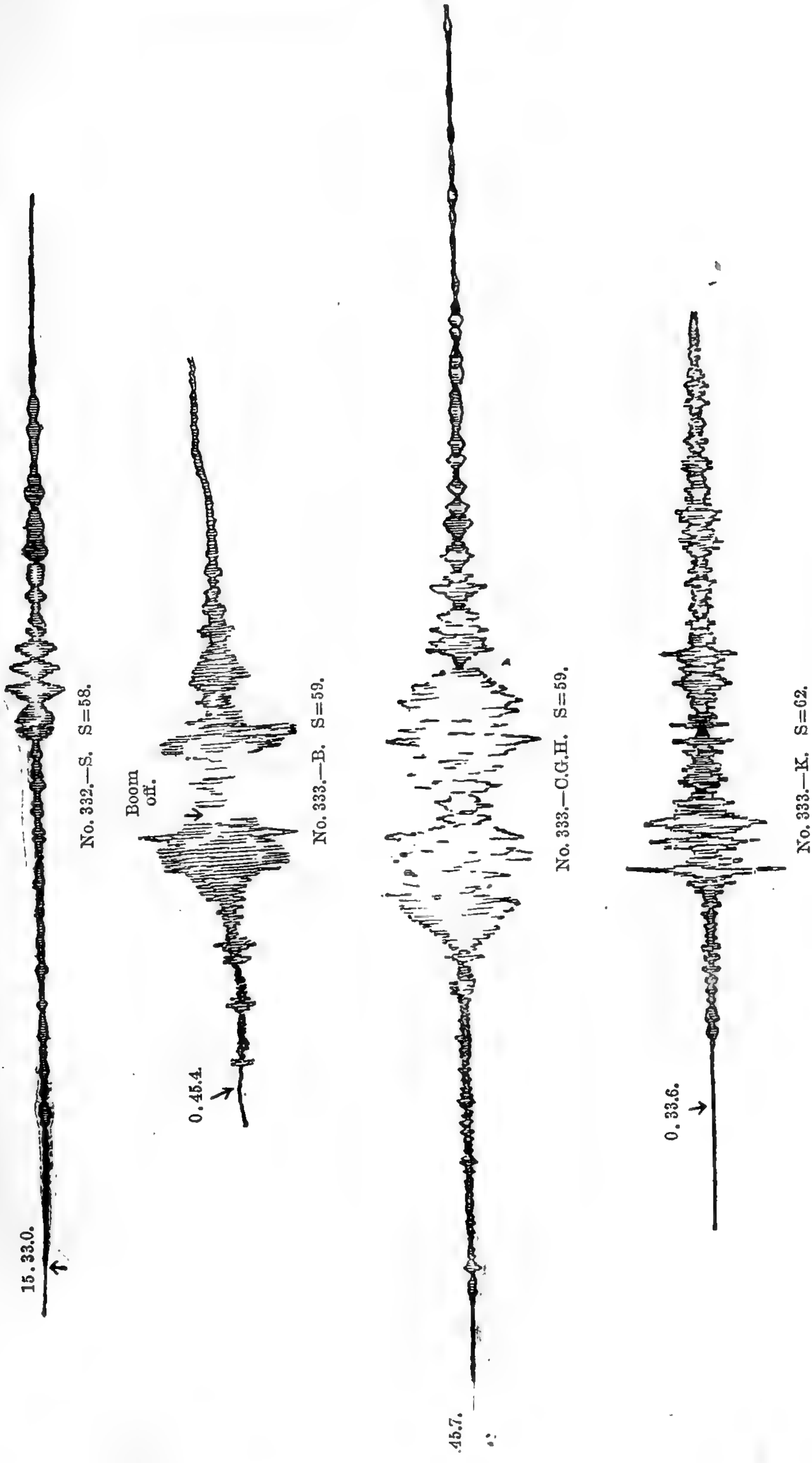
No. 324.—Ba. S=59.

4.53.1.

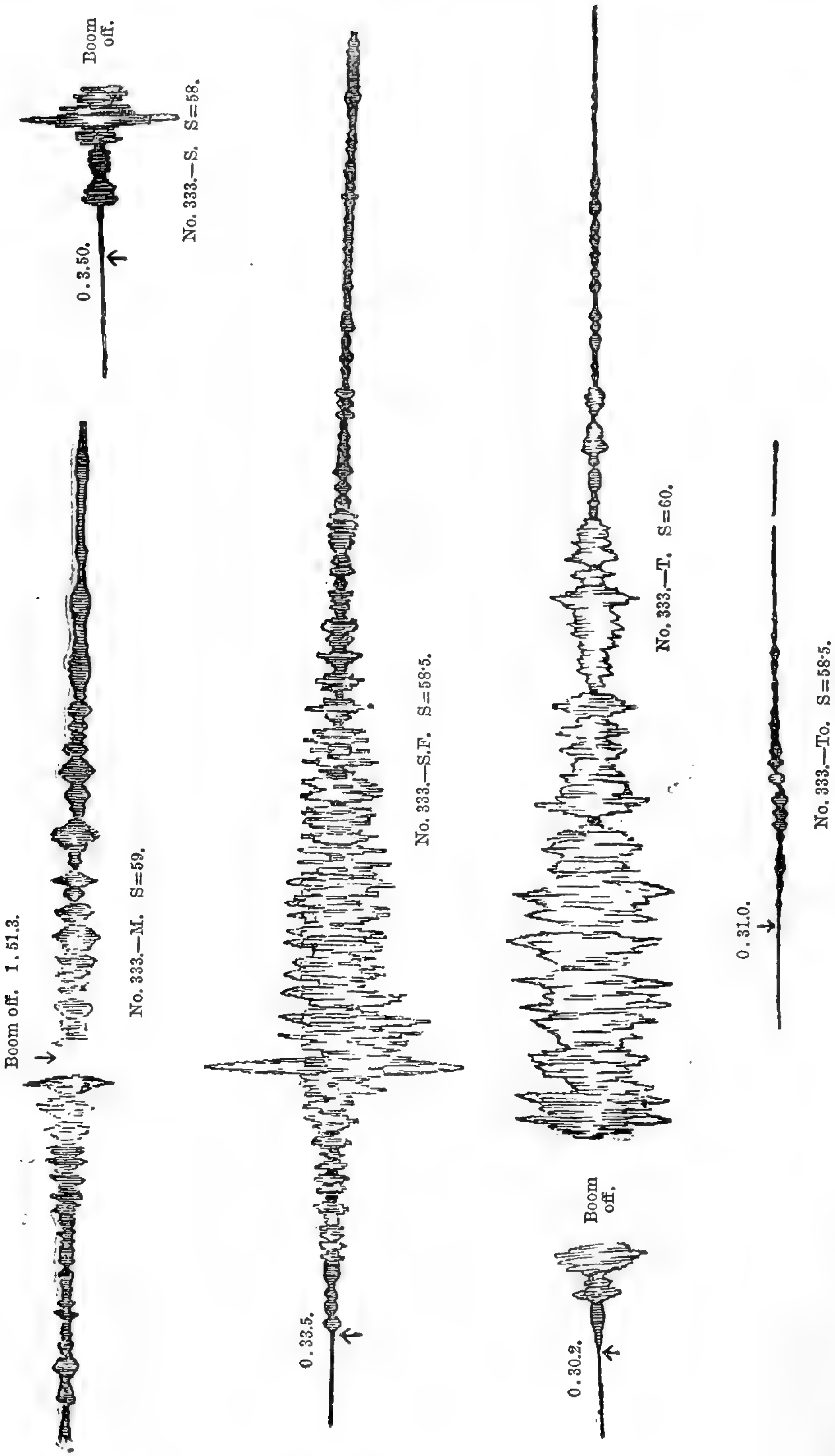


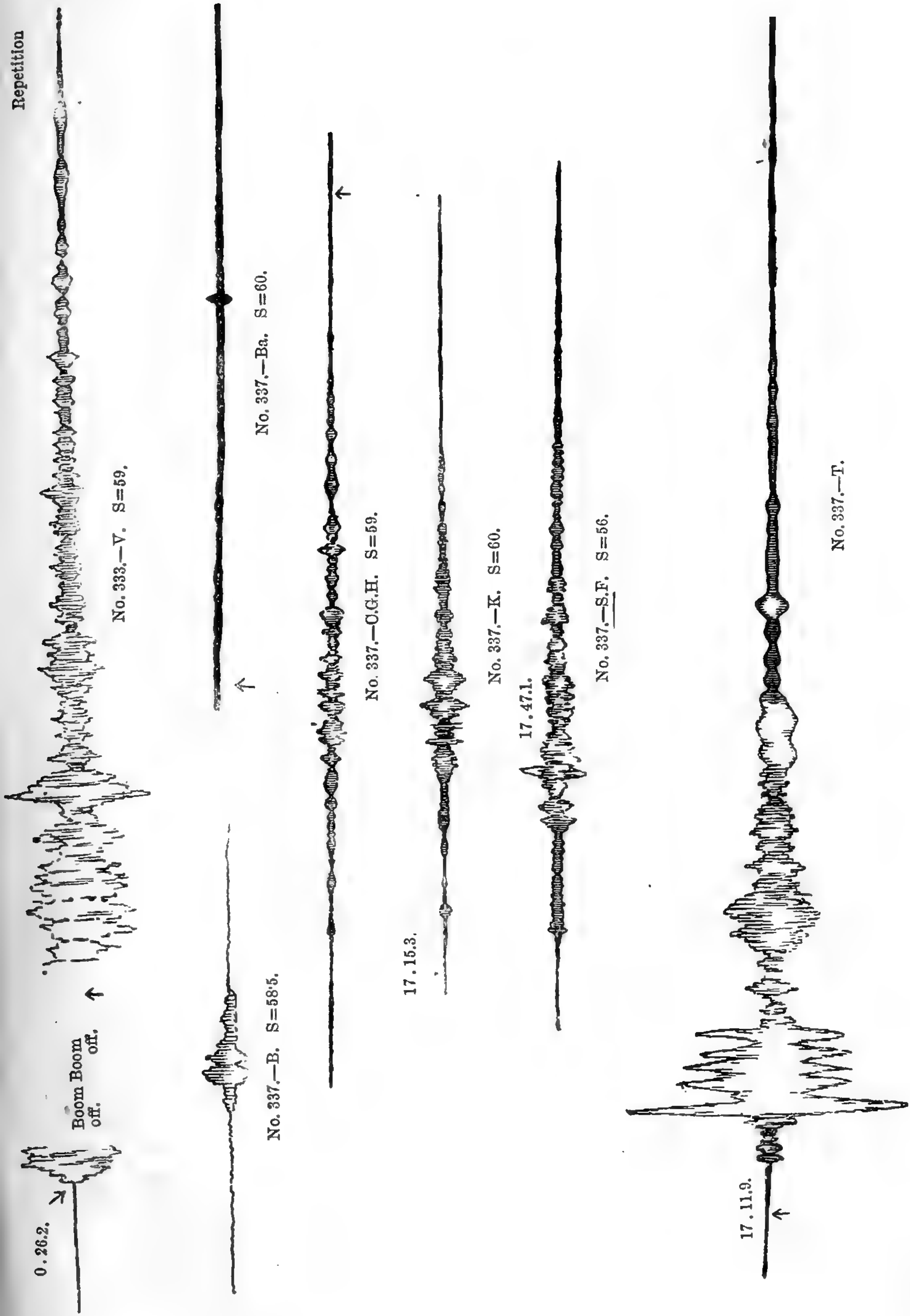
No. 324.—C. S=58·5.


4.56.1.
No. 324.—M. S=60.
No. 324.—C.G.H. S=59·5.
No. 324.—S. S=58.
5.4.6.
No. 324.—T. S=58·5.
5.3.0.
No. 324.—V. S=60.
4.58.3.
No. 332.—Ba.
No. 332.—C.G.H. S=59.
Air Tremors
16.19.0.
No. 332.—M. S=58·5.

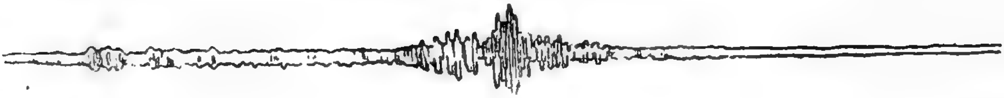


15. 33.0.
No. 332.—S. S=58.
Boom off.
0. 45.4
No. 333.—B. S=59.
. 45.7.
No. 333.—C.G.H. S=59.
0. 33.6.
No. 333.—K. S=62.

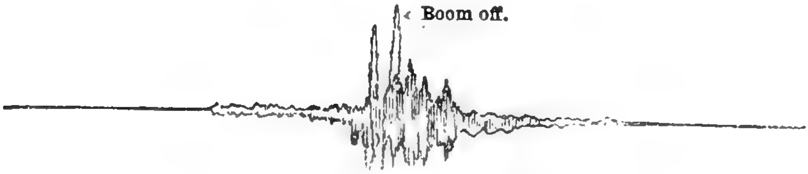

Boom off.
0. 3. 50.
No. 333.—S. S=58.
Boom off. 1. 51. 3.
No. 333.—M. S=59.
0. 33. 5.
No. 333.—S.F. S=58·5.
No. 333.—T. S=60.
Boom off.
0. 30. 2.
0. 31. 0.
No. 333.—To. S=58·5.



Repetition
No. 333.—V. S=59.
0.26.2.
Boom off.
Boom off.
No. 337.—Ba. S=60.
No. 337.—B. S=58·5.
No. 337.—C.G.H. S=59.
No. 337.—K. S=60.
17.15.3.
No. 337.—S.F. S=56.
17.47.1.
No. 337.—T.
17.11.9.

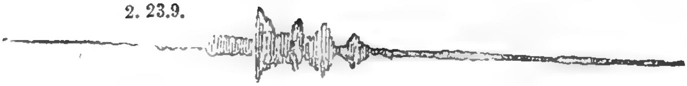


No. 338.—Ba. S=60.



No. 338.—Me. S=59.

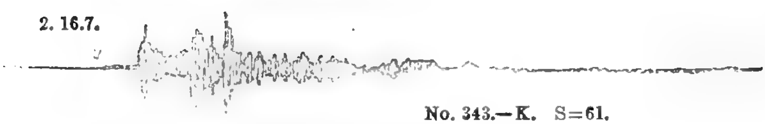
2. 23.9.



No. 343.—B. S=59.

No. 343.—C.G.H. S=59.

2. 16.7.

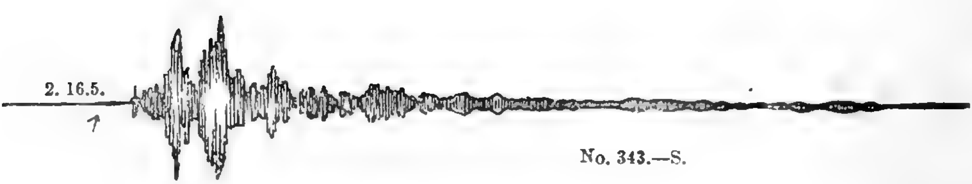


No. 343.—K. S=61.

2 . 59.5.

No. 343.—M. =59.

2. 16.5.



No. 343.—S.

No. 343.—To. S=61.

12. 5.7.

No. 344.—B.

No. 344.—M. S=58.

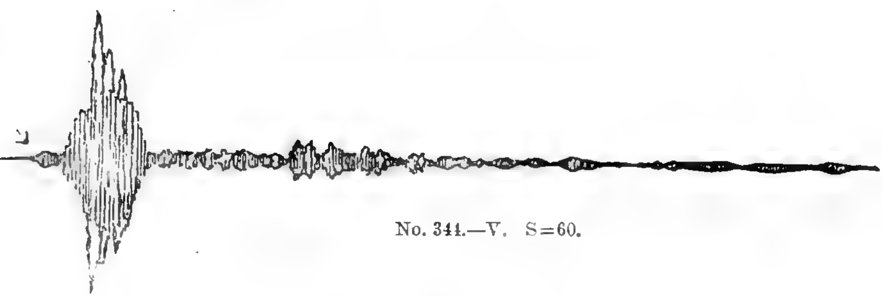
11. 23. 3.

No. 344.—S. S=58·5.

11. 20.9.

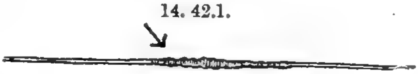
No. 344.—To. S=58.

11. 8.5.



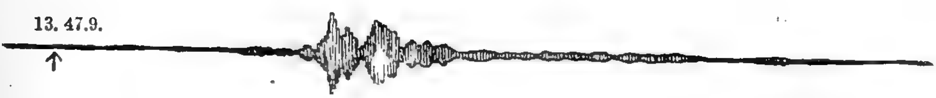
No. 344.—V. S=60.

14. 42.1.



No. 345.—B.

13. 47.9.



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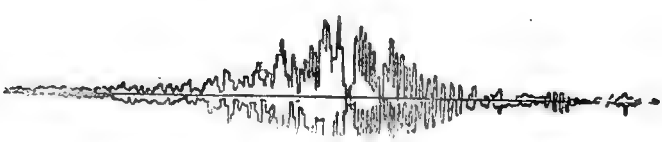
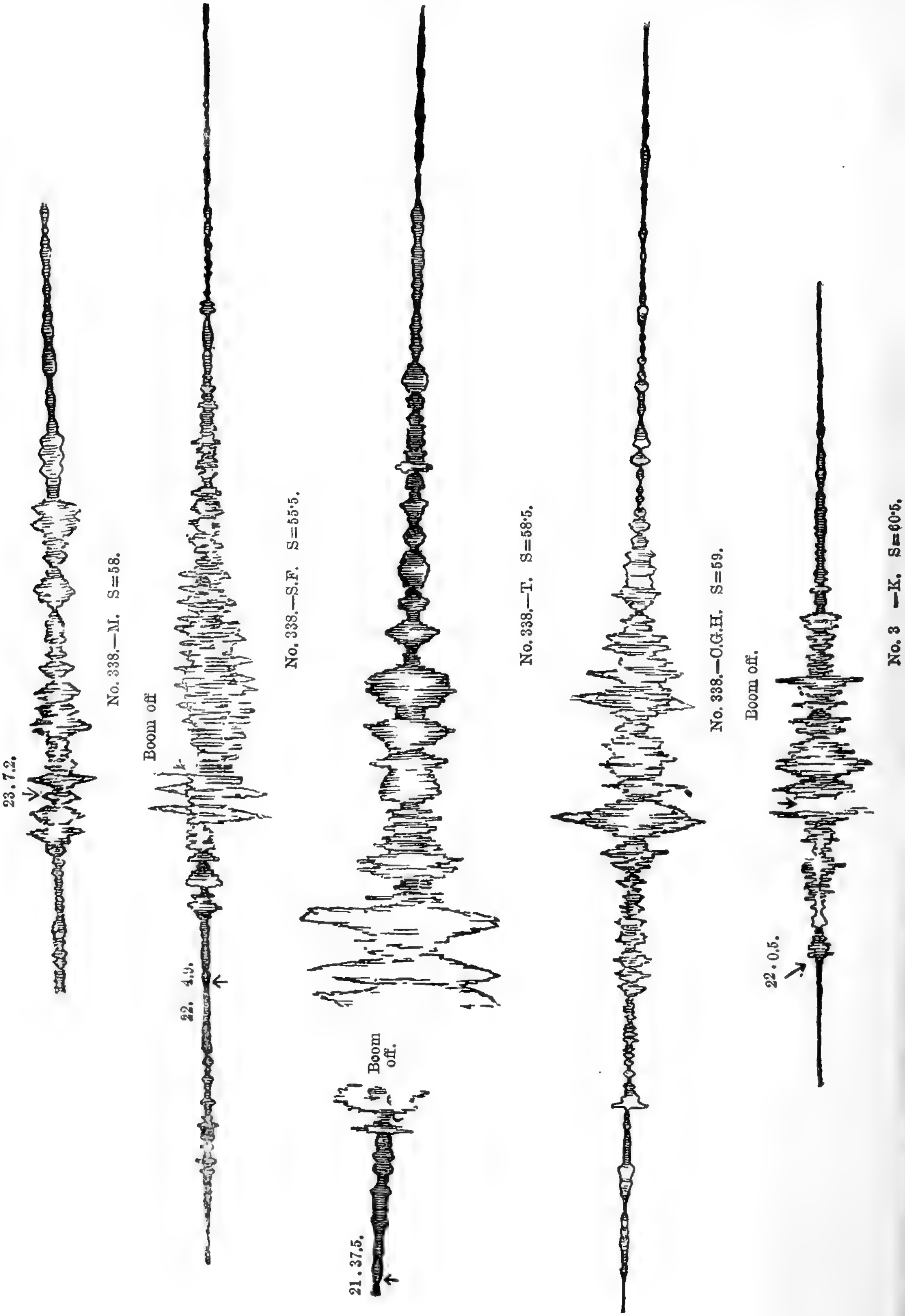
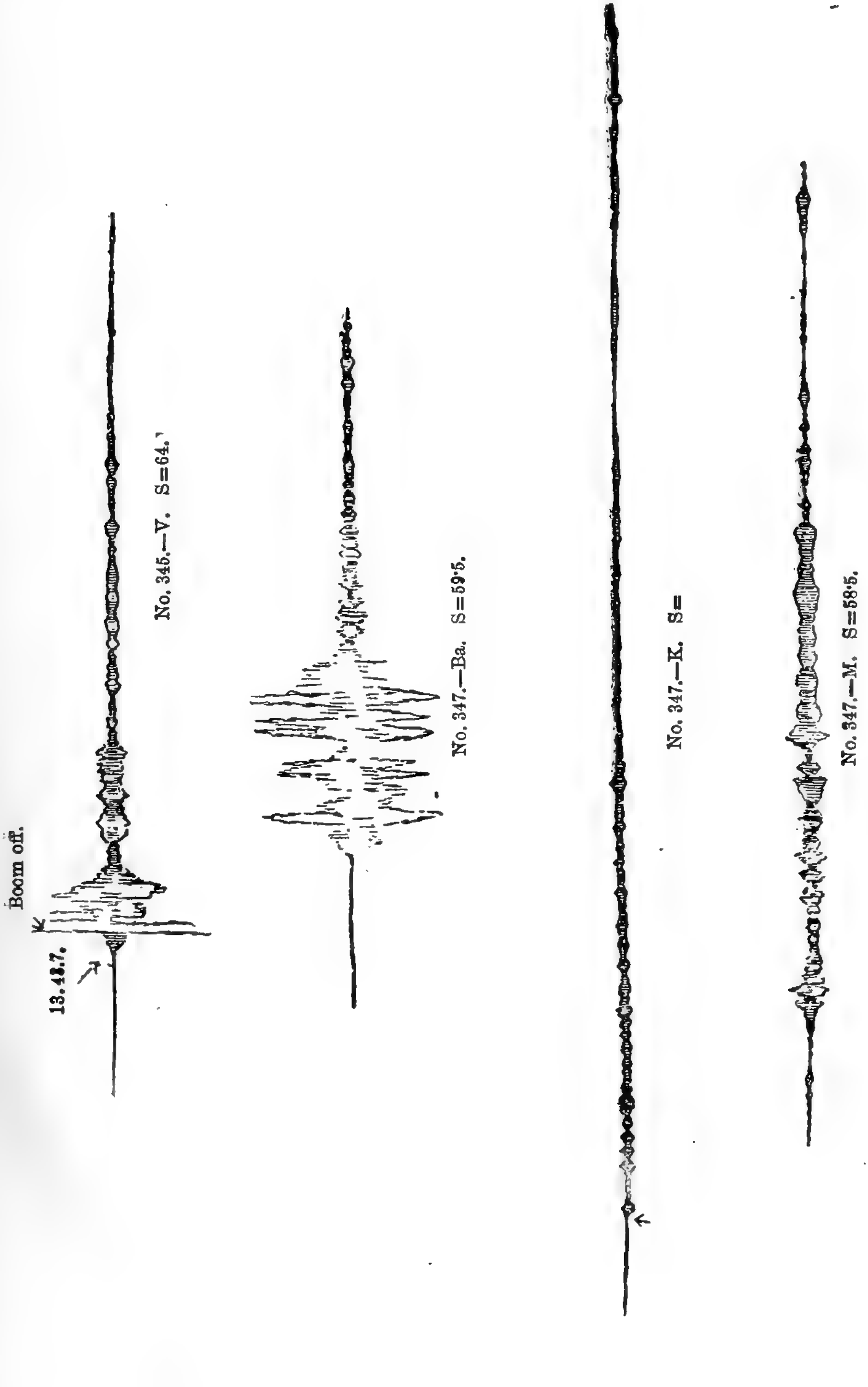
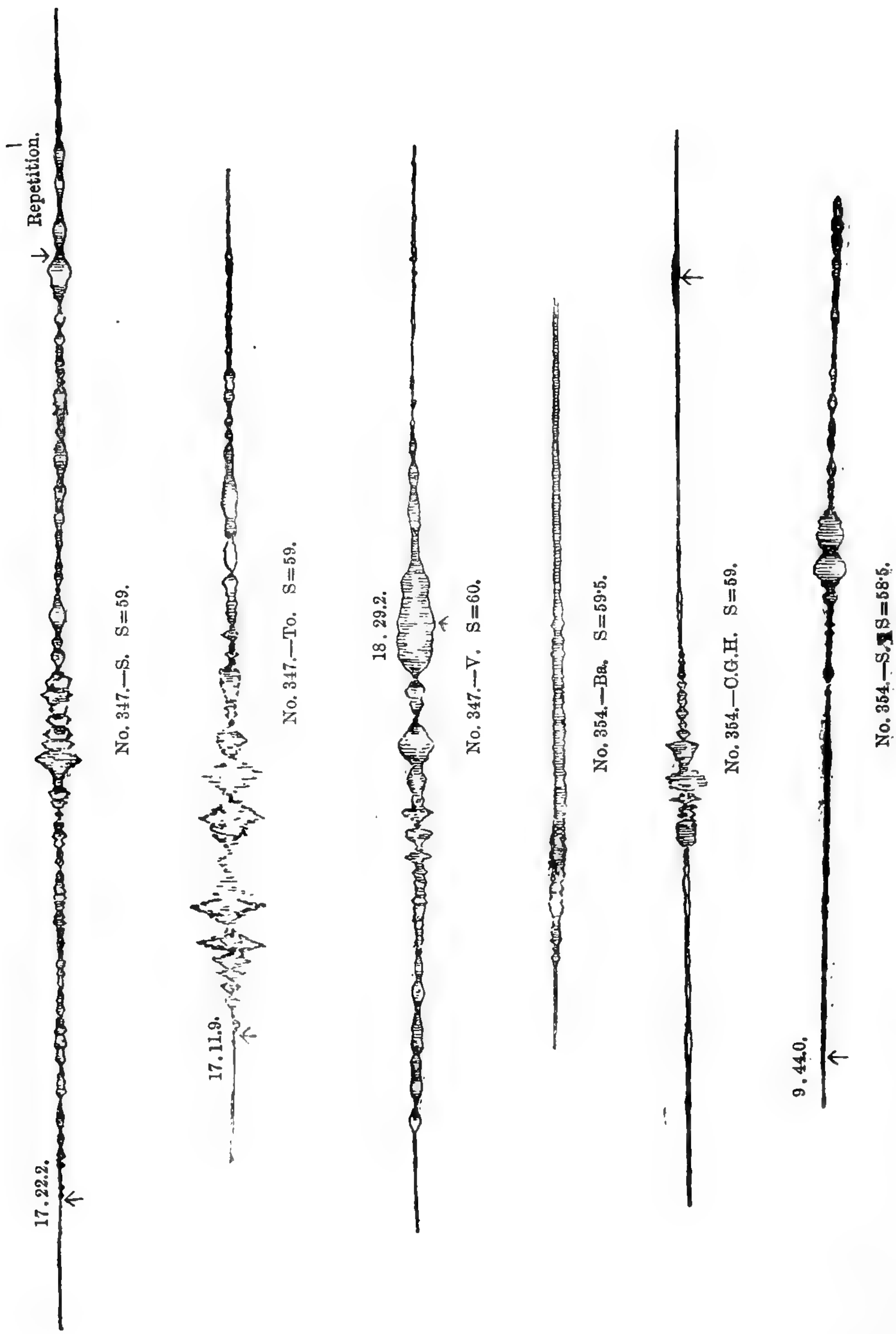
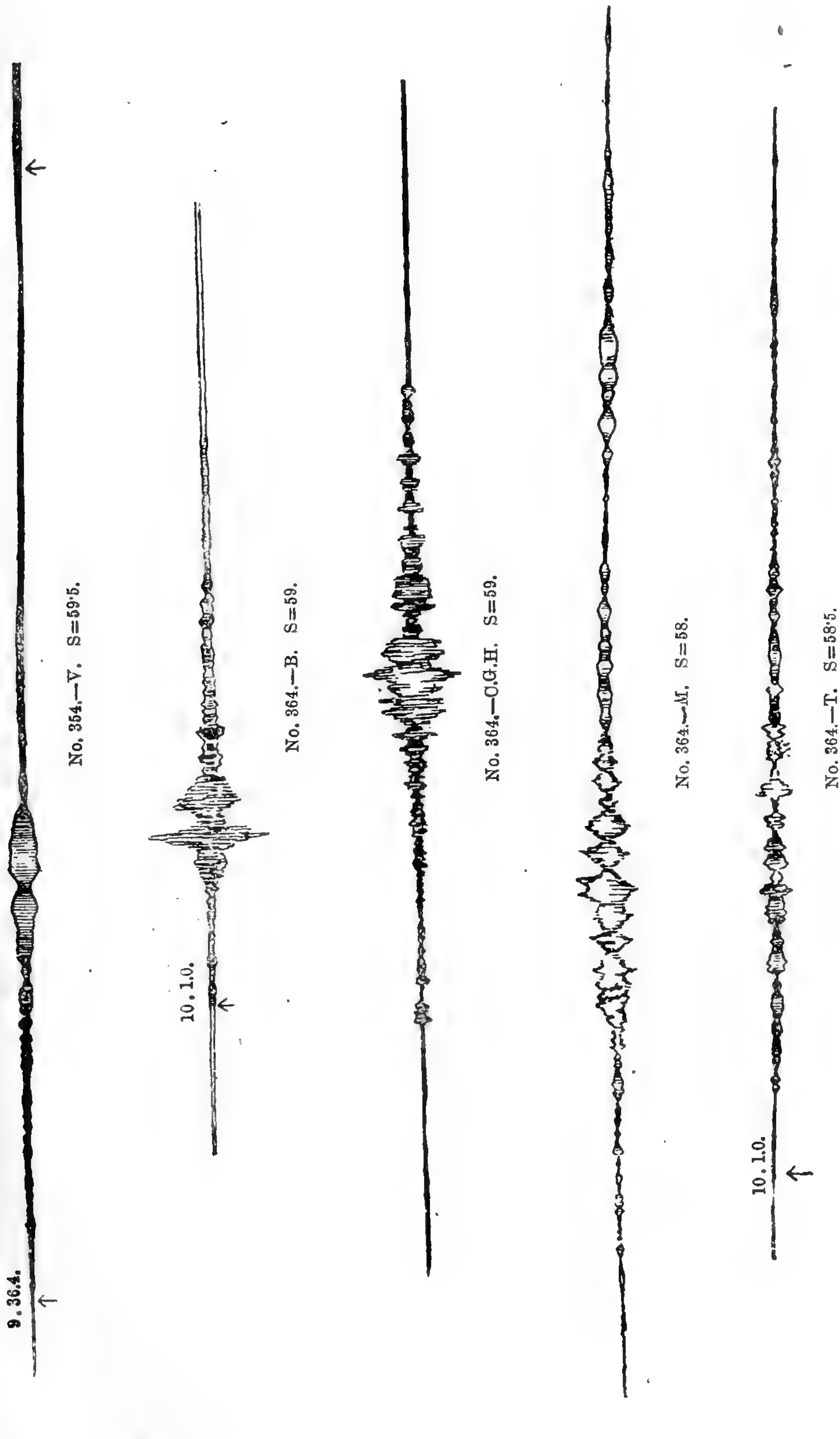


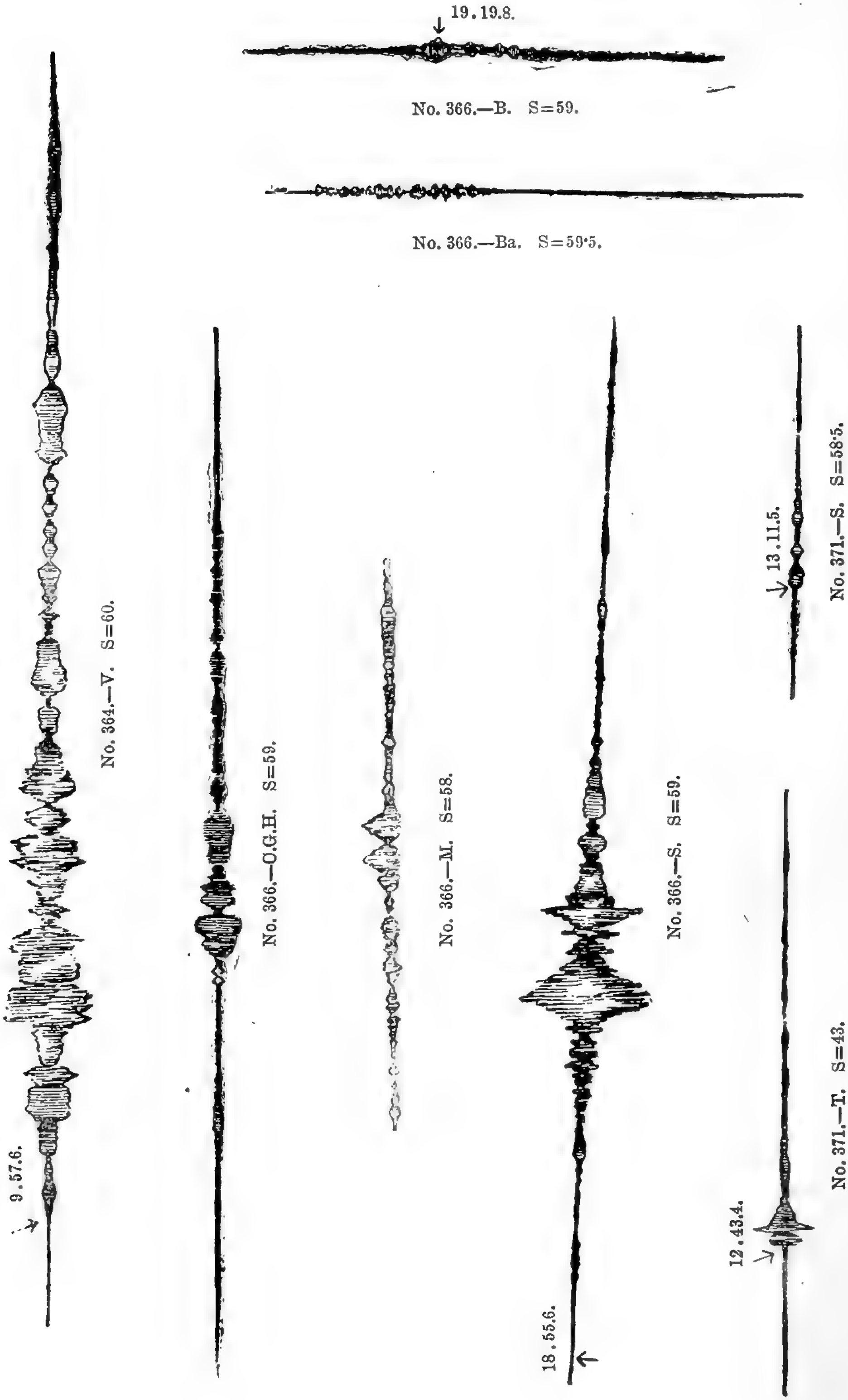
No. 338.—B. S=59.

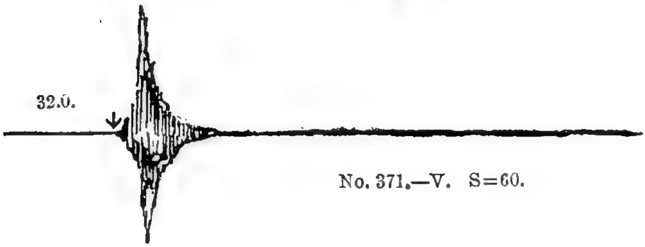

No. 338.—M. S=58.
23.7.2.
Boom off
No. 338.—S.F. S=55·5.
22. 4.9.
Boom off.
21.37.5.
No. 338.—T. S=58·5.
No. 338.—O.G.H. S=59.
Boom off.
No. 3 —K. S=60·5.
22.0.5.


Boom off.
13. 48.7.
No. 345.—V. S=64.
No. 347.—Ba. S=59·5.
No. 347.—K. S=
No. 347.—M. S=58·5.


Repetition.
17.22.2.
No. 347.—S. S=59.
17.11.9.
No. 347.—To. S=59.
18.29.2.
No. 347.—V. S=60.
No. 354.—Ba. S=59·5.
No. 354.—C.G.H. S=59.
9.44.0.
No. 354.—S. S=58·5.


No. 354.—V. S=59·5.
9.36.4.
No. 364.—B. S=59.
10.1.0.
No. 364.—O.G.H. S=59.
No. 364.—M. S=58.
No. 364.—T. S=58·5.
10.1.0.


19.19.8.
No. 366.—B. S=59.
No. 366.—Ba. S=59·5.
No. 364.—V. S=60.
9.57.6.
No. 366.—O.G.H. S=59.
No. 366.—M. S=58.
No. 366.—S. S=59.
18.55.6.
13.11.5.
No. 371.—S. S=58·5.
12.43.4.
No. 371.—T. S=43.



III. *Earthquakes and Timekeepers at Observatories.*

That earthquakes we can feel frequently accelerate, retard, or stop clocks with pendulums is a fact well known, but the extent to which cryptoseismic disturbances which sweep over the whole surface of our globe many times per year affect this class of timekeepers has not yet been investigated.

Father J. de Moidrey, S.J., of the observatory at Zikawei, gives me the following notes on this subject. On June 12, 1897, 'an excellent clock facing north lost 4m. 44·5s. in the afternoon, whilst another, almost identical, fixed to the same brick pillar, but facing east, was undisturbed (rate 0·1s.). Secchi's barograph shows a slight stroke at 11h. 25m. G.M.T., corresponding to an oscillation of 1 mm. of the quicksilver.

'A fast moving barograph (mercury) shows a spot at 11h. 23m., indicating a swing of the mercury of 0·25 mm. This increased to 0·50 mm. and died out suddenly.

'The magnetographs, declinometer, bifilar and Lloyd's balance were all disturbed, although it was a day of perfect magnetic calm.'

On this day, at 11h. 5m. G.M.T., a violent earthquake took place in Assam. The large waves of this would reach Zikawei at 11h. 21m. G.M.T., or 7h. 26m. 43s. P.M. local time.

In a second letter Father Moidrey writes:

'On June 4, 1898, about midnight, our north clock lost about four seconds. That same night at a watchmaker's in Shanghai several clocks (six, I believe), all facing north or south, were stopped. Nothing else was noticed by the watchmaker, M. Vrard, who in his surprise telephoned to the observatory to ask what was the matter. Nobody in the town felt an earthquake, nor was one referred to in the newspapers. A missionary at Nankin had his clock stopped the same night, but did not notice any other phenomena. Our magnetograph and thermograph recorded a shock at 16h. 24m. 17s., June 3, G.M.T. On that day there was an earthquake at Chemulpo, Corea.'

We are here evidently dealing with an earthquake recorded on June 3 at 17h. 14m. at Shide, and also recorded at Kew, Nicolaiew, and Potsdam.

From the 'Bulletin Mensuel' of Zikawei, third quarter, 1897, we learn that in the night of September 2 the two clocks were stopped and the magnetographs were disturbed at 1.42 (September 1, 17h. 36m. G.M.T.). Nothing was felt. This may refer to an earthquake recorded at Shide, September 1, 18h. 29m. G.M.T.

Although Professor E. C. Pickering writes me that on September 3, 10 and 23, 1898, which are dates for heavy earthquakes in Alaska, and on September 20, when there was a severe earthquake in Asia Minor, there were no noticeable changes in the rates of the clocks at Harvard

University; the observations made at Zikawei indicate that at certain observatories at least the unfelt movements of earthquakes may from time to time have serious effects on timekeepers.

With the object of throwing light upon this subject I shall esteem it a favour if directors of observatories will let me know whether any changes were observed or *not observed* in the rates of pendulum time-keepers on dates corresponding to those of large earthquakes enumerated on p. 108, addressing their communications to me at Shide, Isle of Wight, England.

IV. *Earthquakes and Rain.*

In the British Association Reports for 1899, p. 209, I gave a quotation from Mr. O. H. Howarth respecting a heavy condensation of aqueous vapour which he observed for three hours after the Mexican earthquake of January 24, 1899. This was in the form of a heavy mist which settled over the head of a cañon at an elevation of 8,700 feet.

Mr. Howarth states that in this place such mists are never seen at this time of the year, it being the middle of the dry season.

Something similar to this occurred on June 12, 1897, after the severe earthquake which originated on that day in the highlands of Assam. Mr. H. Luttman-Johnson, I.C.S., in the 'Journal' of the Society of Arts, April 15, 1898, describes the weather before the earthquake as having cleared: the afternoon was lovely, and there was not a cloud in the sky. Five minutes after the earthquake the residents in Shillong were surrounded with cloud and mist, and they sat up all night with rain beating upon all sides.

Captain A. A. Howell, I.C.S., deputy-governor of the Garo Hills, gives the actual rainfall. The records taken at 8 A.M. showed that for the twenty-four hours preceding the 12th there was no rain. There was rain at noon on the 12th, but it cleared off at 2 P.M. The earthquake occurred at about 5 P.M., and after that until next morning 3·26 inches fell.

In considering whether there is any possibility of a connection between the phenomena here considered we must remember that observations showing that rain and cloud have followed closely on the heels of certain earthquakes appear to be confined to tropical and semi-tropical countries; and it is in these countries where sudden showers, indicating the collapse of critical atmospheric conditions, are frequent. Given, therefore, such conditions at no great distance above the surface of the earth, which was probably the condition in the highlands of Assam, and then admit that beneath the gaseous covering consisting of layers of air of different temperatures and with different degrees of saturation 10,000 square miles of mountainous country was moved, or that a much larger area was thrown into violent wave-like movement, we recognise that the relationship of earthquakes and atmospheric precipitation may not be so improbable as is generally supposed. As the ground rose upwards, the air immediately above it would suffer compression, and as the ground fell there would be rarefaction, whilst layers of air differing in their physical state might be mixed, and a vigorous seismic activity might in this way result in precipitation.

V. *Earthquakes and Small Changes in Latitude.*

In vol. xvii. of the 'Seismological Journal of Japan,' 1893, p. 17, I drew attention to the observation that the period of maxima increase in latitude in Berlin apparently coincided with maxima of earthquakes recorded in Japan.

If we compare the wanderings of the pole from its mean position for the years 1895–1898 [1] with registers of earthquakes which have disturbed continental areas or the whole world, we find a somewhat similar relationship. This is shown in the accompanying table, the pole displacements being measured from Albrecht's figure.

—	1895		1896		1897		1898	
	Displacement	Earthquakes	Displacement	Earthquakes	Displacement	Earthquakes	Displacement	Earthquakes
1. January 1 to February 5	0″·03	1	0″·07	1	0″·14	5	0″·12	4
2. February 5 to March 14	0·03	2	0·04	1	0·11	7	0·11	0
3. March 14 to April 19	0·06	0	0·05	1	0·07	1	0·07	4
4. April 19 to May 26	0·07	1	0·08	2	0·11	5	0·08	5
5. May 26 to July 1	0·08	1	0·10	2	0·13	5	0 10	6
6. July 1 to August 7	0·03	1	0·11	0	0·11	6	0·16	5
7. August 7 to September 12	0·05	0	0·10	4	0·10	5	0·15	6
8. September 12 to October 19	0·06	1	0·13	3	0·07	5		
9. October 19 to November 24	0·06	1	0·10	4	0·11	4		
10. November 24 to December 31	0·08	1	0·13	0	0·12	1 or 4		
Totals	0·53	9	0·91	18	1·07	44 or 47	0·79	30

A conclusion suggested by this table is that, during intervals when the pole displacement has been comparatively great, large earthquakes have been fairly frequent, and *vice versâ*. In the yearly totals this is marked.

If we turn to a figure given by F. R. Helmert, showing variations in latitude as determined from 353 sets of photographic records made on forty-two days in the months of April, May, and June, 1897 (see 'Bericht über eine neue Reihe von Polhöhen-Bestimmungen, &c., im Jahre 1897,' F. R. Helmert, Potsdam), we see that successive daily means frequently differ from 0″·1 to 0″·2 amongst themselves. Equally large differences exist between the separate observations from which these means are deduced.

That is to say, successive observations may show differences as great as the annual maximum displacement of the pole, which is about 0″·25 from a mean position.

If on Helmert's figure we plot the large earthquakes for these months, it is seen that in the time of their occurrence they closely coincide with

[1] See *Bericht über den Stand der Erforschung der Breiten-Variation am Schlusse des Jahres* 1898, von Th. Albrecht.

the times at which large deviations in latitude occur. In April, when these deviations were comparatively small, large earthquakes did not occur.

When considering the possibility of any relationship between earthquakes and these extremely frequent and practically oscillatory changes in latitude, there are two points of importance to be remembered.

The first is that with each of these earthquakes there is a sudden shifting of a large mass of material at a seismic origin. The molar displacement for the Indian earthquake of June 12, 1897, is estimated by Mr. R. D. Oldham by an area of 6,000 or 7,000 square miles, and it is not improbable that earthquakes which have caused the Pacific Ocean to oscillate for a period of twenty-four hours were accompanied by displacements of larger magnitude.

The second consideration is that each of the large earthquakes here considered has been accompanied by surface or distortional waves which in many instances affect the whole surface of the globe. These waves, so far as we can infer from their velocity, period, and maximum angle of inclination, vary between twenty and seventy miles in length, and are from a few inches to two or three feet in height. If they attain the magnitudes here given (see p. 83) they seem certainly sufficient to relieve a district in orogenic strain.

A further test of the suggestion that slight nutational effects may result from earthquakes would be to compare observations indicating small changes in latitude made before and after the times of large earthquakes referred to in the report, the more important of which are as follows:

						H.	M.
No. 250.	Origin	Mexico,	January	24,	1899,	23	44
,, 333	,,	Alaska,	September	4	,,	0	11
,, 337	,,	,,	,,	10	,,	16	51
,, 338	,,	,,	,,	10	,,	20	21
,, 343	,,	Smyrna,	,,	20	,,	2	9
,, 347	,,	Ceram,	,,	29	,,	17	9
,, 381	,,	Mexico,	January	20	1900,	18	31

The times given are the approximate times at the origin. These are expressed in Greenwich mean time (civil). 0 or 24 hrs. = midnight. The times at which the large waves reached any distant station may be calculated by the application of Curve II*a* or II*b* in the table on p. 67.

VI. *Selection of a Fault and Locality suitable for Observations on Earth-Movements. By* Clement Reid.

The selection of a favourable site for observations upon differential movement between the two sides of a fault presents many difficulties, and the locality we have chosen is more to be regarded as the best available than as ideally perfect. Leaving out of account for the present considerations other than geological, there are certain conditions, most of which must be complied with if the observations are to be of real value.

The fault selected must be:

1. Of considerable magnitude, and not be merely a branch fault which the next earth-movement may easily leave unaffected.

2. It should be of known date, and belong to a recent geological period. This consideration is important, for a Tertiary movement is far

more likely to be still in progress than is one which can only be shown to affect Palæozoic or Secondary rocks. Not only have the older movements in many cases ceased long since, and have given place to movements in different directions ; but a fault which has long remained without movement tends to become closed and re-cemented, so that there is a considerable likelihood that any future movement may not follow exactly the same line, even though the strain be in the same direction.

3. The fault should crop out on ground fairly level, and in hard rocks, otherwise the observations may be masked by the slight irregular 'creep' of the surface downhill, and no firm foundation for the apparatus be obtained.

4. It is desirable that the rocks on the two sides of the fault, though geologically far apart, should be as like as possible in lithological character, so that any surface movements due to change of temperature or absorption of rain-water should affect the two sides alike.

5. In order to avoid complications through slow solution of the rocks by percolating rain, a fault bringing together insoluble silicious rocks would be preferable to any other.

6. As the records to be obtained may throw great light on movements of the earth's crust, it is desirable that the fault selected for observation should be one belonging to a set of disturbances of great magnitude, having common characteristics, and affecting a considerable area. It is therefore important that the district chosen should be one which has been carefully studied geologically, and of which the structure is thoroughly known.

These various conditions, added to the consideration of convenience of access of the locality, availability of a skilled observer, availability of the land, and other minor points, made a series of requirements not easy to satisfy, and I will now indicate in what respects the site finally selected comes up to or falls short of the ideal set before us.

Consideration No. 2 confines us at once to the only area in Britain in which large earth-movements of Tertiary date can clearly be proved to have taken place. This area may be taken to lie between the North Downs and the English Channel, and to extend as far west as Weymouth and Abbotsbury. But only the parts of it in which Tertiary rocks are still preserved will do for our purpose ; the reason being that older movements of the same general character affected the Jurassic and Lower Cretaceous rocks. These intra-Cretaceous disturbances cannot always be distinguished from the Tertiary movements, in the absence of the unconformable Upper Cretaceous and Tertiary strata. Thus in the Wealden area a good many faults are believed to affect the Lower Cretaceous rocks ; but they are of no great magnitude, and it is impossible at present to differentiate those of Tertiary date from the older series.

We are thus confined, by a process of elimination, to the sharply folded belt which occupies the southern part of the Hampshire Basin and includes the northern half of the Isle of Wight. Even over this area it would only be possible to use Mr. Horace Darwin's apparatus at certain points ; for much of the country is sharply folded without faulting, and any earth-movements now in progress could only be measured by careful levelling and triangulation. Thus we are confined ultimately to a limited highly disturbed and faulted belt, which extends east and west through the centre of the Isle of Wight and reappears in Dorset between Studland Bay and Abbotsbury.

Within the area thus selected are various sharp monoclinal folds, all with an east and west axis, and with the strata so bent as to become nearly vertical. In places the lateral pressure and folding have been so violent as to pass into overthrust faulting on a considerable scale. None of the Tertiary disturbances in this part of England is a normal drop-fault; the supposed north and south Tertiary fault in the Medina valley, though often shown in old maps and text books, having no existence.

The date of most violent disturbance in the system of folds above alluded to is clearly later than Middle Oligocene; for in the Isle of Wight the Hamstead Beds, which belong to that period, and are the newest Tertiary strata there preserved, are tilted at a high angle. From various considerations, which need not here be recapitulated, it seems probable that this set of disturbances commenced in Eocene times, became most violent in the Miocene period, and died away in Pliocene times.[1] Though in our south-eastern counties older Pliocene strata to some extent have been tilted, the disturbance has not yet been shown to affect newer deposits, or to be still in progress. This last is one of the principal points which our apparatus should decide.

Consideration No. 1 limits our choice to a small group of faults, not more than half-a-dozen, and as the apparatus employed needs a fairly clean-cut fracture, unless the pipes are to be of unreasonable length, it is only at a few points on these faults that the observations can be made. We have thus so greatly reduced the number of possible points at which the apparatus could be fixed, that it will now be simplest to describe the faults one by one, and point out to what extent they do or do not fulfil the rest of the requirements.

Working from east to west, the first Tertiary fault met with is in the main monocline of the Isle of Wight, which occasionally passes into a thrust-fault of no great extent. In one place the basement bed of the London Clay is brought against Bracklesham Beds; but the strata are too soft and full of water to yield satisfactory fixed points. In the others, plastic Clays of the Reading Series have slid over Chalk, the bedding being vertical and the surface slope very high. At no point in the Isle of Wight could a satisfactory site be found.

Following this disturbed belt westward, we again meet with a sharp monoclinal fold, passing into a slide-fault, at Ballard Cliff in Dorset. This is the well-known 'Isle of Purbeck Fault,' which thrusts Chalk with flints with curved bedding over similar rock with the bedding vertical. The fault itself is very conspicuous in the cliff-face, curving through about a tenth of a circle in a height of 280 feet.[2] This fault might be a good one for observation; but though it is of considerable magnitude, the locality is by no means convenient of access. The disturbance is, however, a valuable one to study, for its character is clearly shown in the section. The other faults with which we are now dealing apparently are all of this type.

The next Tertiary fault met with is close to Corfe Castle, where in the sharpest part of the monoclinal curve the London Clay has been thrust over the Reading Beds and abuts against the Upper Chalk. This slide-fault is of small magnitude, and as in similar slides in the Isle of Wight,

[1] Reid and Strahan, 'Geology of the Isle of Wight,' chapter xiv. *Memoirs of the Geological Survey*, 1889; Reid, 'Pliocene Deposits of Britain,' chapter v. *ibid.* 1890.

[2] See Strahan, 'Geology of the Isle of Purbeck,' chapter xv. *Mem. Geol. Survey*, 1898.

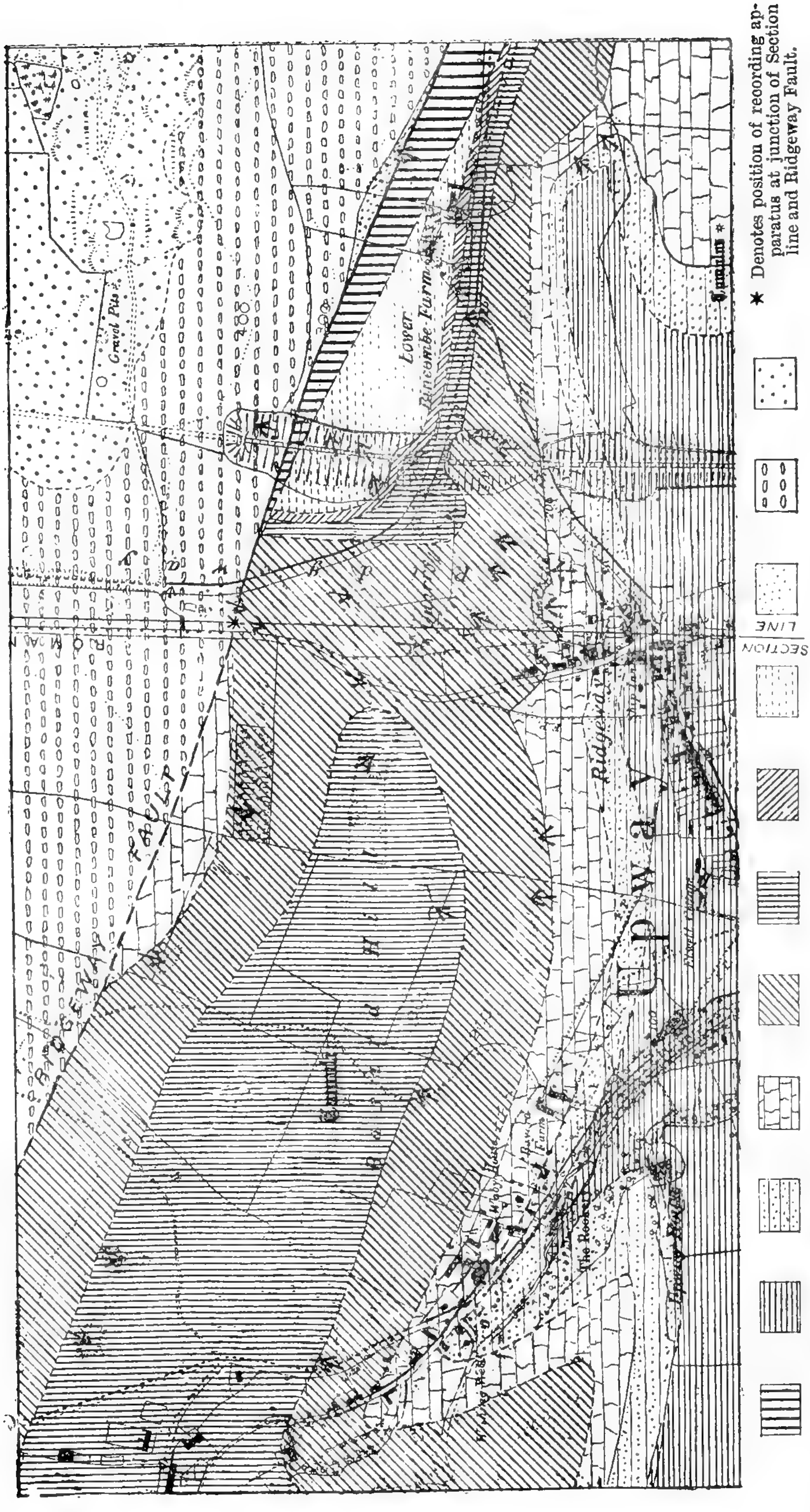
the ground is too steep and the rocks too soft to yield satisfactory fixed points. Along the same line the junction of the Chalk and Eocene is again slightly faulted near Lulworth; but the fault is of small magnitude, and the adjoining rocks are too much shattered for our purpose. The Durdle fault runs parallel with and close to high cliffs, so that delicate observations might be entirely masked by movements caused by the gradual removal of large masses of rock by the sea on the south and the consequent rise of the strata on that side. At Bat's Head the Isle of Purbeck Fault is finally lost beneath the sea, and the shattering of the rocks is too great to allow of exact observations. This fault does not reappear in the Weymouth area.

There still remains one of the most important Tertiary disturbances in the district, that known as the Ridgeway fault. This also is an over-thrust fault cutting through a monocline, or through the north limb of a sharp anticlinal fold. Its date is clearly later than the Bagshot period; its magnitude is great, and if any of the Tertiary faults are still undergoing changes, this one is likely to partake in the movement. It brings together rocks of very different ages and of varying character, so that the choice of exact locality for the observations depended on the discovery of a spot where the fault is a clean fracture, where the rocks on each side are hard and of fairly similar lithological character, and where the ground is sufficiently level for the apparatus. Along a good deal of its course there is much fault rock or broken ground, and in most parts the strata on one or both sides are soft. These parts would not be convenient or satisfactory for our purpose. For various reasons the choice narrowed down to the neighbourhood of Poxwell, where Middle or Lower Chalk abuts against Lower Purbeck; or to the district between Upway and Portisham, a distance of four miles, where Upper Chalk is faulted against strata close to the base of the Lower Purbeck, or even against Portland Beds. Of these localities Upway was chosen (fig. 2), for there the deep railway-cutting has laid open the structure of the disturbance, and within a reasonable distance, though not too near, was a piece of fairly level ground, one end of which had been opened for chalk-pits and the other for quarries in the Purbeck Beds. The railway-cutting itself would not have been satisfactory, for in it a wide dyke of 'fault-rock,' composed of Oxford Clay and Cornbrash, occurs, and south of the fault there are soft rocks. Besides this, soft strata in a deep cutting will almost certainly be subject to slow 'creep' to such an extent as entirely to mask any deeper-seated movement.

The site finally selected proved by an unexpected series of coincidences to be particularly convenient. It is broken ground, now only used for rough pasture and not liable to be disturbed by the plough; it belongs to Gonville and Caius College, Cambridge, who have most kindly done all in their power to help us in the experiment. Our thanks are not only due to the College, but also to the tenant for his assistance in carrying out the work. And last, but not least, it was conveniently accessible to the member of the Committee who was prepared to undertake the recording.

While our excavations were being made I examined them, and noted as exactly as possible the geological conditions in the immediate neighbourhood, for the fault varies within very short distances, and has changed completely in the two hundred yards between the railway cutting and our selected site. In that short distance the dyke of Oxford

FIG. 2.—Geological Survey Map of Upway, by A. STRAHAN; with additions by CLEMENT REID. (Scale, 6 inches = 1 mile.)



Clay has disappeared entirely, as is the case with the Middle Chalk on the north side of the fracture, as well as the Wealden and Upper and Middle Purbeck on the south side. The fault has also become a fracture of unusual sharpness for one of so great a magnitude.

In discussing the character and extent of thrust of the fault at Ridgeway, it should not be forgotten that it does not pass through a series of conformable strata. The Upper Cretaceous rocks here rest unconformably on a folded and greatly eroded surface of Lower Cretaceous and Jurassic strata, so that the local absence of Wealden and of most of the Purbeck may be due to this unconformity. These intra-Cretaceous folds have an axis approximately parallel with the much later Tertiary disturbances. The most important of them is the wide anticline between Upway and Portland. This is followed northward by a narrow and sharp syncline, which brings in the Wealden and Purbeck between Upton and Bincombe, and passes unconformably under Upper Cretaceous rocks towards the east and towards the north-north-west. Next follows an anticline, which is almost entirely hidden by the newer rocks. It is touched at Poxwell, where the Jurassic strata dip northward at a higher angle than the Upper Cretaceous. It then seems to run beneath the Chalk parallel to the southern boundary just north of the Tertiary overthrust. Its southern limb reappears at Bincombe, but soon disappears again beneath the overthrust mass of Chalk. The position and character of these earlier folds, their relation to the Upper Cretaceous overlap, and the relation of both to the overlap of the Bagshot Beds on to the Oolite,[1] are the factors which produced a continuous plane of weakness extending obliquely downward from the surface deep into the Jurassic strata, as shown in the diagram (fig. 3).

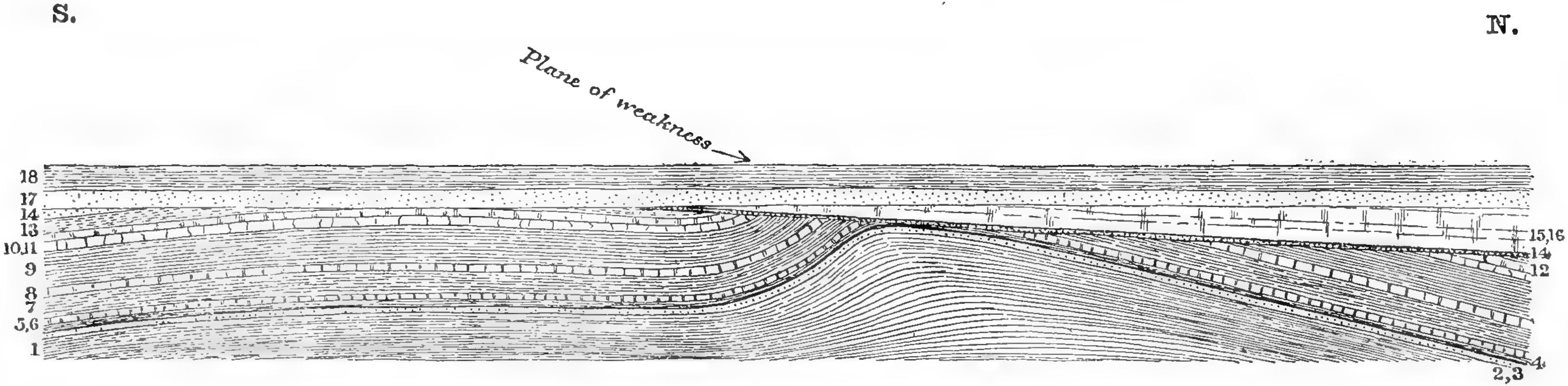
The outcome of this geological structure has been that any subsequent lateral compression in a north and south direction causes the massive Chalk, over 800 feet thick, to be driven against the wide arch of rigid Purbeck and Portland rocks extending towards Portland. Any such movement must tend still more to fold and buckle the already existing small anticlines and synclines; but the main arch of hard Upper Jurassic rocks would offer great resistance, as would the horizontal thick-bedded Chalk. Thus the Chalk must approach the main anticline, overriding the minor folds, taking with it such parts of them as happened to be above the plane of greatest weakness, and smearing the slide-plane with Oxford Clay and Cornbrash caught up in the passage over the northern limb of the anticline.

The above explanation will, I believe, account for the whole of the curious phenomena recorded along this line of fault. Granted north and south compression, any differential movement must be along this plane of weakness. The extent of the differential movement must also be greatest at the surface where the plane emerges, and must rapidly decrease downward and northward until the fault entirely disappears. The extent of the movement in this case is probably about half a mile.

From the data in the memoirs and maps of the Geological Survey, and from my notes made more recently, I have constructed the subjoined geological section across the fault at the point where our apparatus is fixed (fig. 4); but though the underground structure must be not unlike that indicated, the exact curve of the fault, and also the exact character

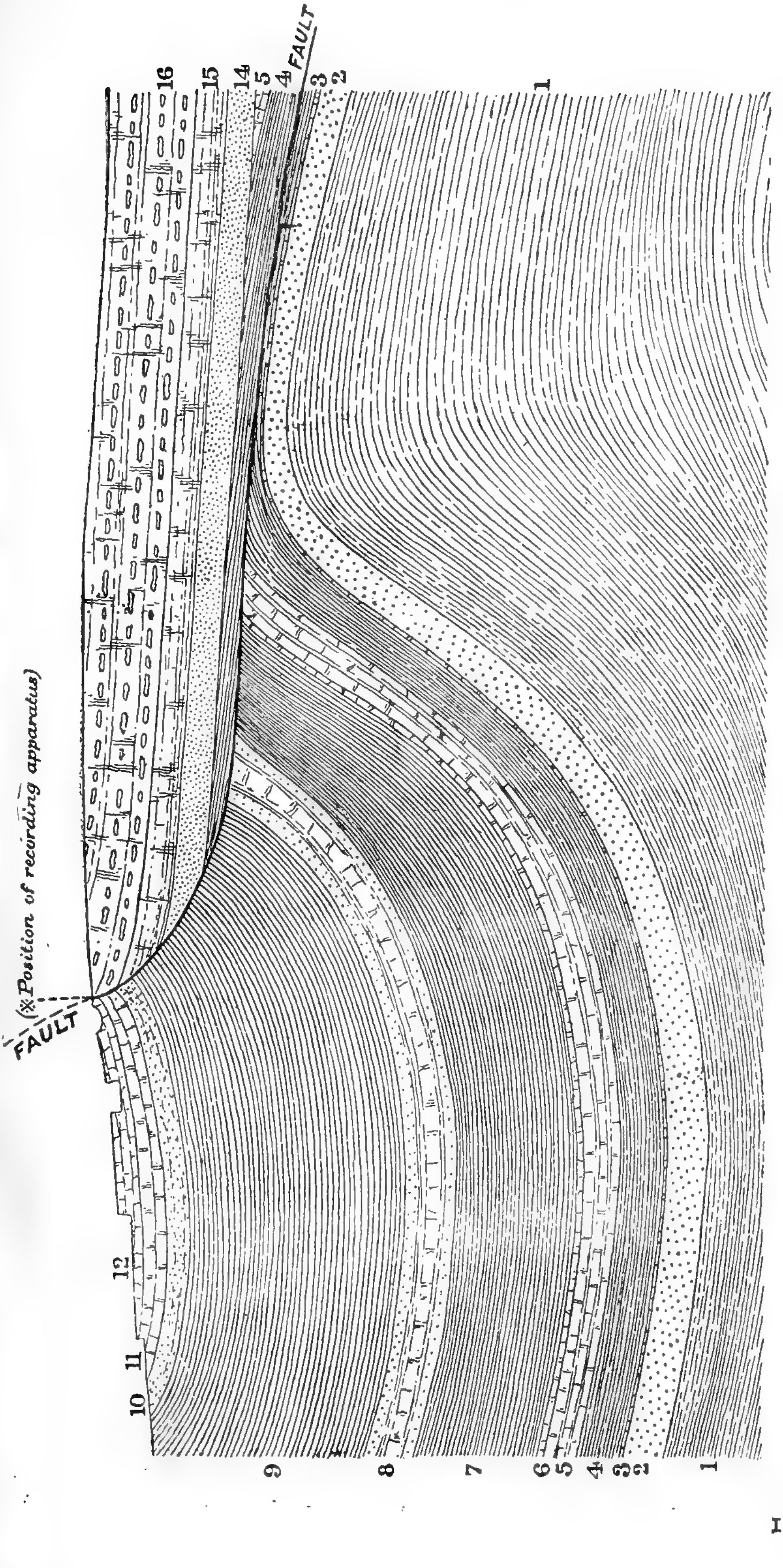
[1] See Reid, 'Geology of Dorchester,' chapter vi., *Memoirs Geol. Survey*, 1899.

FIG. 3.—N. and S. Diagram Section, showing probable structure before the formation of the Ridgeway Fault. (Scale, 1 inch = 1 mile.)



18 Oligocene.
17 Bagshot.
16 Upper Chalk.
15 Middle and Lower Chalk.
14 Upper Greensand.
13 Wealden.
12 Purbeck Beds.
11 Portland Stone.
10 Portland Sand.
9 Kimeridge Clay.
8 Corallian.
7 Oxford Clay.
6 Cornbrash.
5 Forest Marble.
4 Fuller's Earth.
3 Inferior Oolite.
2 Midford Sand.
1 Lias.

FIG. 4.—Section across the Fault at Ridgeway. (Scale, 6 inches = 1 mile.)

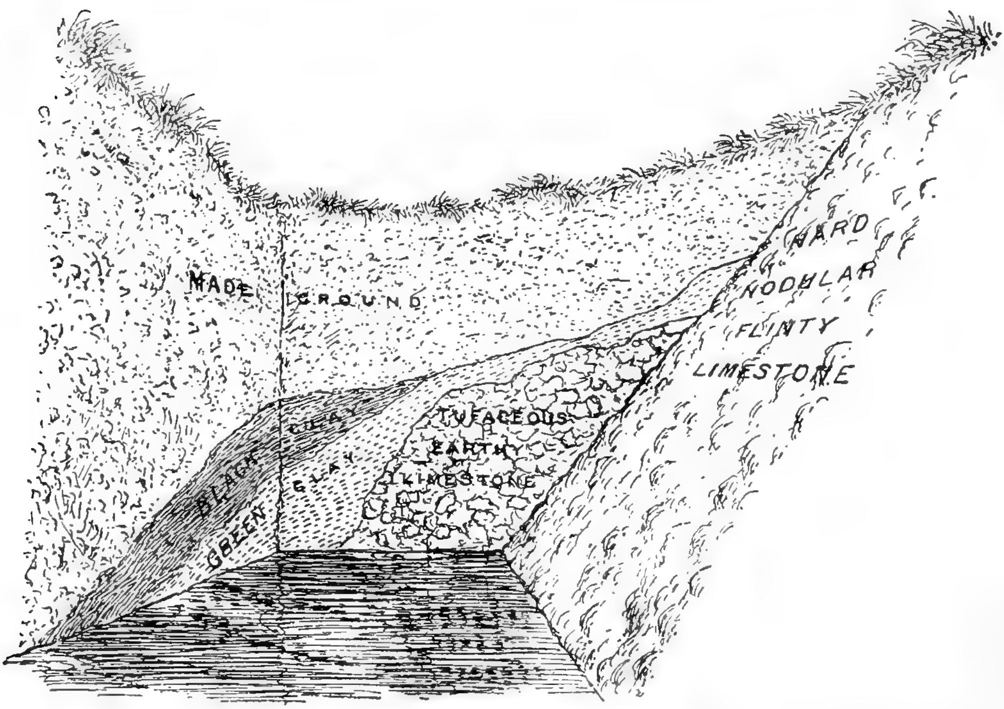


16 Upper Ch alk.	12 Purbeck Beds.	9 Kimeridge Clay.	6 Cornbrash.	Inferior Oolite.
15 Middle and Lower Chalk.	11 Portland Stone.	8 Corallian.	5 Forest Marble.	2 Midford Sand.
14 Upper Greensand.	10 Portland Sand.	7 Oxford Clay.	4 Fuller's Earth.	1 Lias.

of the hidden folds beneath the Chalk, must remain uncertain. The Eocene deposits are not shown in this section, as they happen to have been denuded along the line selected. They occur only a short distance away out of the line of section. The actual evidence seen at the surface close to our site will now be described.

On the south side of the fault the strata dip northward at varying angles for a distance of about two miles from the crest of the main anticline, the lowest rocks in the district occurring in this anticline north of Radipole, where the Forest Marble appears at the surface. To this succeed in order the Cornbrash, Oxford Clay, Corallian Rocks, and Kimeridge Clay, followed at Upway (at the south border of the map, fig. 2), where the slope becomes steeper, by Portland Sand, Portland Stone, and Lower Purbeck Beds. The lower quarries at Upway are in Portland

FIG. 5.—Section of Lower Purbeck Rocks, dipping at 52°.



Rock, dipping north; the higher are in Lower Purbeck, nearly horizontal, for at that point the lowest part of a synclinal fold is reached and the strata begin to rise again.

Higher up the hill in quarry and road-cutting the sections are nearly continuous, the dip being about S.S.W. at angles varying from 15° to 30°. Signs of lateral compression are also common, this being particularly well seen on the west side of the quarry nearest to the fault, where in a few yards the dip changes from nearly horizontal, with small sharp folds, to an angle of 15°. At the extreme north edge of this quarry the Committee undertook special excavations in order to clear up the geology at a point close to the fault. We followed a particular rock bed to a depth of 9 feet from the surface, obtaining the subjoined section, seen from the east (fig. 5). The strata laid bare belong to the 'dirt-bed' of the

Lower Purbeck, and occur within a few feet of the Portland Rock. The strike is almost parallel to the fault, though more nearly east and west. Thus it becomes almost certain that Portland Beds crop out at the surface immediately east of the Roman road and are probably within less than 10 feet of the surface at the point where the recording apparatus crosses the fault.

Taking now the trench in which the apparatus is placed, we will describe the strata there seen on each side of the fault. The trench is 9 metres long, and at the four observing stations (see Mr. Horace Darwin's Report, p. 119) sections were exposed to a depth varying from $5\frac{1}{2}$ to 7 feet. At Station SS (the southernmost) the depth was $5\frac{1}{2}$ feet, of which the top 3 feet was in disturbed ground, the lower $2\frac{1}{2}$ showing hard brownish fine-grained oolite with fossils, the rock being somewhat shattered, with small open fissures, which were afterwards filled in with concrete. This rock undoubtedly belongs to the Lower Purbeck ; it seems to dip at a high angle in a southerly direction, the strike, however, not being parallel with the fault. The shallower trench between Stations SS and S showed similar strata, though no fossils or oolitic grains were observed. At Station S the hole was also $5\frac{1}{2}$ feet deep ; the rock being a hard splintery brown limestone, more or less nodular and containing small chert nodules. I believe that this rock corresponds with some cherty limestones which are seen in the large Upway Quarry, just below the 'dirt-bed' and within 5 or 10 feet of the base of the Purbecks. Near the fault, however, they are harder and more crystalline than in the quarry. I was not able to find the earthy and carbonaceous 'dirt-bed' at this point, though it is so well seen only 50 or 60 feet away (see fig. 5). The squeezing-out or thickening of a soft stratum is, however, a phenomenon constantly to be met with near a big disturbance, and the absence of the carbonaceous seam is probably due to this cause. The south cheek of the fault consists of brecciated white limestone with chert. These exposures seem to indicate that the Portland Stone must occur within 5 feet or so of the surface close to the fault, and on the strength of the new evidence I have added an inlier of Portland rock to the map made by Mr. Strahan, who agrees with me that such an addition is necessary.

The fault itself is represented by a band of fault-rock not more than 2 feet in thickness and quite unlike the wide dyke of mingled Oolite and Oxford Clay seen in the railway-cutting. In our trench the fault-rock is a hard mass of breccia consisting of Upper Chalk and fragments of Purbeck Limestone.

The north cheek of the fault consists of very hard shattered and re-crystallised flinty chalk like that associated with the similar disturbances at Corfe Castle and at Ballard Cliff, though at Ridgeway I did not observe actual calcite veins. Two feet north of the fault I dug out a specimen of *Ananchytes ovatus ;* but this echinoderm and a few fragments of *Inoceramus* were the only fossils I could find in the Chalk in our trench. The flinty character of the Chalk and the presence of the *Ananchytes* show, however, that we have passed suddenly from Lower Purbeck to Upper Chalk, and the character of the Chalk and of the included flints indicates, I think, that we are at an horizon above the Micraster-zones and probably at least 300 feet above the base of the Chalk.

Between the fault and Station N the Chalk gradually becomes softer and less crystalline and contains small broken flints, black with moderate rinds. The hole at Station NN showed 6 feet of moderately hard Chalk,

with numerous brownish-grey flints; the Chalk being fissured but not altered. At Station NN the hole was 7 feet deep and exhibited Chalk with numerous flints, the rock being much slickensided and fissured. It contained a few fragments of *Inoceramus.* I was not able anywhere to get a satisfactory dip in the Chalk in the trench or holes; though the general impression suggested was of an ascending succession northward, and of a high dip in that direction.

The general results of the geological examination may thus be summarised. The fault, at the point where the apparatus crosses it, probably cuts out strata having a thickness of nearly 1,000 feet, made up thus:—

Chalk (part of Upper, whole of Middle and Lower)	300
Greensand and Gault	150
Wealden	350
Upper Purbeck	50
Middle Purbeck	50
Lower Purbeck (to within 5 feet of base)	85
Total feet	985

The break, however, is not caused by a normal fault of 985 feet throw. It is the result of a sliding movement over a cylindrical surface curving downward and northward from nearly vertical to nearly horizontal. This view, as pointed out by Mr. Strahan, explains the presence of a dyke of Oxford Clay and Cornbrash in the railway-cutting; a fact which cannot be satisfactorily accounted for by normal faulting, even to the extent of 2,500 or 3,000 feet. The movement along the curve of the thrust-plane amounts to not less than 2,500 feet, even if the strata are everywhere vertical to the fault. It is just possible, however, that earlier faulting along nearly the same line in intra-Cretaceous times brought up Cornbrash, so that it occurs immediately beneath the Upper Cretaceous rocks just north of the Tertiary fault. On this supposition, and with the most favourable angle of dip throughout, the Tertiary thrust may not exceed 500 feet. The most probable estimate of the extent of the Tertiary displacement is, however, about half a mile; a lower estimate demands an improbable series of fortuitous coincidences, such as we are not justified in postulating.

There is one point that I should like to suggest for future consideration. The disturbances just described result from lateral compression of the strata in a north and south direction, and it is clear that levelling across the fractures will only give us one element in that motion. The horizontal movement must be of much greater magnitude than the vertical, and could be accurately tested by triangulation. As the folds have always an east and west axis, and there is no sign of disturbance in other directions, triangulation across the folds from fixed points lying east and west ought to enable us to test whether any change is now going on over wider areas. Even a comparison of the earlier Ordnance triangulation of the South of England with the later one might throw light on this question, if the stations can be identified with sufficient accuracy. No minute re-measurement of a base-line would be necessary for this test. If the movement is going on at all it must be far greater in a north and south than in an east and west direction—*i.e.*, it will alter the latitude but not the longitude. It must therefore distort every triangle which can be re-observed from two such points as St. Catherine's Down and the top of Portland.

VII. *An attempt to detect and measure any relative movement of the strata that may be now taking place at the Ridgeway Fault near Upway, Dorsetshire.—Preliminary Report by* HORACE DARWIN, *August* 1900.

The Fault for this experiment was selected by Mr. Clement Reid, and is described by him in a separate report. It would have been better if the rock had been harder and more impervious to water; the solubility of the carbonate of lime in the rock is also a disadvantage. The site is easy of access, an essential point in such an experiment; this, together with the advantages pointed out by Mr. C. Reid, justify the selection of the Fault.

The Fault where the apparatus is fixed is a few yards east of the Roman road and about 560 yards north of the cross roads in the village of Upway, Dorsetshire, and is about 360 feet above Ordnance datum. Gonville and Caius College, Cambridge, allowed the apparatus to be fixed on their property and did all in their power to make the experiment successful, and the Committee are most grateful to them. I must thank Mr. Nelson Richardson for the many hours' help he gave me at Upway, and in arranging for the experiment, and for the readings he took afterwards. Thanks are also due to Mr. Loveless, the tenant of the land, for the care he has taken in carrying out the work and the help he gave in every way.

Four positions were taken in a straight line approximately at right angles to the fault; these positions will be denoted by the letters N.N., N., S., S.S.; N.N. is 9 metres and N. $4\frac{1}{2}$ metres north of the Fault, and S.S. is 9 metres and S. $4\frac{1}{2}$ metres south of it. The apparatus is arranged to measure the relative vertical movement of the strata at these four stations. There are advantages in selecting four instead of two stations. If there had been only two stations, and the apparatus got damaged at one of them, the experiment must have been a failure; also, if there had been any accidental displacement of the apparatus relatively to the strata at either of the two stations it might have led to misleading results. With four stations such damage or movement will probably be detected, and the results, though less valuable, will not be rendered quite useless, as would be the case with only two stations.

The movement of the strata at the Fault may take place in any or all of the following ways:—

(1) The strata on both sides of the Fault may tilt as a whole without any slip taking place at the Fault.

(2) The strata at the north side may tilt and the south side not tilt, and still no slip at the Fault.

(3) The strata at the south side may tilt and the north side not tilt, and still no slip at the Fault.

(4) There may be slipping at the Fault with no tilting.

These four movements may be all taking place at the same time, and the use of four stations will allow of each movement being separated from the others.

The apparatus has been designed by me and made by the Cambridge Scientific Instrument Company, Limited. I have not been able to give sufficient time this summer to overcome some difficulties which I regret that I did not foresee, and it is for this reason that no numerical results

are given in this report. The instrument, however, promises well, and I hope next year to give a description of it and numerical results; now I only propose to explain its general principle.

A brass casting is permanently fixed to the rock at each of the four stations, and it is the relative vertical movement of these castings which is measured. A stand carrying a microscope can be placed on any of these castings; it has three feet, each in the form of an inverted V, and these rest on three cylindrical pieces forming part of the brass casting. This is the usual geometrical arrangement, giving six points of contact, and determining absolutely the relative position of the microscope stand and the casting. The microscope is about 4 feet long, and thus the eye is in a convenient position for taking an observation. The microscope is moved vertically in the stand by a micrometer screw, and carries at its lower end a needle pointing vertically downward. The micrometer screw is turned, the microscope is lowered till the needle point touches the surface of some oil contained in a vessel fixed to the rock, and the position of the micrometer screw noted. The microscope and stand are then removed and placed on the other castings, and the observation repeated; in this way the relative position of the casting at each station to the oil surface is measured. The four oil vessels are connected by a pipe; the surface of the oil is therefore at the same level. The needle point is illuminated by a mirror fixed in the oil vessel, and the light, leaving it in a nearly horizontal direction, is reflected by a vertical mirror nearly directly backwards, and is then again reflected vertically upwards through the object-glass and eyepiece of the microscope. On looking vertically downwards through the microscope, the needle point and its reflection in the surface of the oil are seen as if the eye were placed just above the surface of the oil; and when the micrometer screw is turned the needle point and its image are seen to approach each other. The moment of contact is perfectly evident; the needle and its image appear to run into each other in a confused manner, owing to the distortion of the oil surface when the needle point touches it. The delicacy is considerable; the divisions in the divided head of the micrometer screw correspond to a movement of $\frac{1}{100}$ mm., and it is easy to estimate a tenth of these divisions, but I do not think that the readings can be trusted to this amount, and it is proposed only to read to $\frac{1}{100}$ mm., which is well within the power of the instrument.

The micrometer readings give the height of each station above the oil surface, and from these readings is deduced the movement at each station relatively to a datum plane. This datum plane is taken at the mean level of the four stations. The necessary calculations also prevent any error arising from change of the oil level due to expansion or evaporation, damage to the needle point, or expansion of the microscope.

It is hoped that a very small slip at the Fault will be detected and measured, but even if the movement should ever become as much as 10 mm. to 20 mm., it can still be measured with great accuracy. It is unlikely that such a movement will damage the lead pipe where it crosses the Fault; damage to the pipe, however, can be easily remedied without impairing the accuracy of the readings. Some readings have been taken, but it is feared that they are not perfectly trustworthy; they may, however, be useful in confirming later results.

Report on the Present State of the Theory of Point-groups.—PART I.

By FRANCES HARDCASTLE, *Cambridge.*

CONTENTS.

§ 1. INTRODUCTION.

THE term point-group is a direct translation of the German word *Punktgruppe,* first used by Brill and Noether in the year 1873 in their classic memoir on algebraic functions,[1] but to my knowledge, although more than a quarter of a century has elapsed since then, there has been no very systematic attempt to present the theory of point-groups to English readers along any of its lines of development. And yet it should prove of interest even to those mathematicians who do not desire to specialise in it, for, historically and logically, it touches upon many distinct branches of pure mathematics. To mention only those which are most directly brought into connection with each other, we have the intersections of plane curves, the elimination of variables from systems of equations, the algebraic theory of correspondences on a plane curve, properties of linear systems of plane curves, and applications of the theory of functions to the theory of curves and surfaces in space of any number of dimensions.

As frequently happens when the progress of a subject has been due to many different writers, the logical and the chronological divisions do not coincide. I have therefore in view a dual arrangement of the subject-matter. In the present instalment of my Report, I have attempted to sketch this proposed arrangement under its two aspects, viz. : as an historical outline (§ 2), and as an analysis according to content (§ 3). This is followed (§ 4) by a detailed account of one of the historical divisions. I hope in the subsequent portions of the Report to deal in a somewhat similar way with the remaining divisions, and to append a complete bibliography.

§ 2. HISTORICAL OUTLINE.

A. 1720–1818. Memoirs on the intersections of plane curves from Maclaurin to Lamé.

[*Lamé was the first to express the linearity of the system of curves through the intersections of two given curves.*[2]]

B. 1818–1857. Memoirs and other published accounts of theorems on the intersections of curves from Lamé to Riemann, including those of Plücker and Cayley.

[*Plücker was the first to introduce explicitly projective methods by*

[1] 'Ueber die algebraischen Functionen und ihre Anwendung in der Geometrie,' *Math. Ann.,* vol. vii., pp. 269–310.

[2] Cf. C. A. Scott, *Bull. Am. Math. Soc.,* vol. iv., p. 262, 1898.

means of homogeneous co-ordinates; [1] *and also to fix one curve in the discussion, treating the other curves as variable.* [2] *Cayley's theorems are interesting on account of the subsequent discussion as to their true formulation.*]

C. 1857–1873. (i.) Memoirs on bi-rational transformation.

(ii.) Brill's memoirs on elimination and algebraic correspondences, (1863–1873). [*A detailed account of these is given in* § 4, *infra.*]

(iii.) Memoirs and other publications connecting the theory of functions with the theory of plane algebraic curves, including those of Clebsch and Gordan, Brill and Noether.

[*Clebsch and Gordan's treatise attempted to found Riemann's results in the theory of Abelian functions on an algebraic basis: the standpoint is mainly that of projective geometry. To Brill and Noether is due the initiation of the main line of enquiry in the theory of linear series of point-groups on a base-curve, from the standpoint of bi-rational transformation.*]

(iv.) Memoirs on the intersections of curves.

D. 1873–1890. (i.) Noether's memoirs published in the *Mathematische Annalen*, and in *Crelle*, on the theory of functions, and on analytical geometry.

(ii.) Memoirs on linear systems of plane curves, treated analytically from the standpoint of bi-rational transformation.

[*These are chiefly by Italian writers, beginning with Caporali in* 1881.]

(iii.) Castelnuovo's memoirs on linear series of point-groups on plane curves, treated geometrically from the standpoint of bi-rational transformation.

(iv.) Segre's memoirs on curves and surfaces in hyperspace.

(v.) Intersection theorems as treated by Bacharach and Zeuthen.

[*These connect Cayley's theorems with Brill and Noether's theorem of residuation.*]

(vi.) Brill's memoirs on algebraic correspondences in the *Mathematische Annalen* contrasted with Castelnuovo's memoir on the number of rational involutions to be found on a curve of given genus (deficiency).

E. 1890–1900. (i.) Castelnuovo's memoir on linear systems of plane curves as determined by given points (1891, *Mem. Torino*, vol. 42).

(ii.) Memoirs on the theory of algebraic surfaces chiefly by Castelnuovo and Enriques, and summarised by them in an article in vol. 48 of the *Mathematische Annalen* (1896).

(iii.) Segre's paper on the geometry on a simply infinite algebraic manifold, in which the properties and applications of linear series are derived from theorems in the geometry of hyperspace (*Annali di Mat.*, vol. 22, 1894).

(iv.) Bertini's account of the principal theorems concerning linear series of point-groups on a plane curve, written chiefly from Brill and Noether's standpoint (*Annali di Mat.*, vol. 22, 1894).

[1] Cf. Brill and Noether, *Jahresber. d. Deutschen Math. Ver.*, vol. iii., p. 297, 1894.
[2] Cf. Brill and Noether, *ibid.*, p. 290.
[3] Cf. Brill and Noether, *loc. cit.*, p. 545.

(v.) Brill and Noether's report on the theory of algebraic functions, containing succinct accounts of the contents and importance of many of the memoirs in the above divisions.

(vi.) Solution of the question of the identity of the terms involution and linear series by Humbert and by Castelnuovo (1893).

(vii.) F. S. Macaulay's papers in the *Proceedings of the London Mathematical Society*, vols. 26, 29, 31, 1895–99, on curves through given points.

§ 3. Analysis according to Content.

A. The three different methods of investigation, viz. analytical, geometrical, transcendental.

B. Various definitions of the terms in use by English, French, German, and Italian writers, and the logical connection of the ideas when defined in the language of analytical geometry.

C. Results obtained by the theory, expressed in the terms defined in B.

(α) Concerning the linear series of point-groups on a given base-curve, *e.g.*, *Clifford's theorem, the Riemann-Roch theorem.*

(β) Concerning the base-curve, proved by means of the properties of linear series of point-groups, and of linear systems of plane curves, *e.g.* :

(*i.*) *Persistence under bi-rational transformation of* p (*deficiency, genus*).

(*ii.*) *Reduction of the order of a curve with given deficiency.*

(*iii.*) *Classification of plane curves into rational, hyperelliptic,* k-*gonal.*

D. Properties of surfaces in hyperspace in connection with the properties of linear systems.

§ 4. Brill's Memoirs on Elimination and Algebraic Correspondences. 1863–1873.

Brill's earliest papers in the *Mathematische Annalen* are on problems which arose naturally out of the subject-matter of his *Habilitationsschrift*, viz. the transformation theory of algebraic functions in connection with Riemann's memoirs on Abelian functions. Clebsch and Gordan, in their treatise on Abelian functions, published in 1866 (the year before Brill's *Habilitationsschrift*), had attempted to develop a theory of the applications of Abelian functions to geometry. Interpreting Abel's and Riemann's equations as curves, they expressed the number p, which plays a fundamental part in Riemann's theory of Abelian integrals, in terms of the singularities of the corresponding plane curve, thus identifying it with the number studied by Cayley under the name of deficiency. They further discussed the persistence of this number under bi-rational transformation—that is, the simplest type of a one-one correspondence—and the existence of certain constants (moduli) invariant under such transformation. Brill adopted their interpretation of the equations, and his work, though essentially analytical in form, is capable of direct geometrical application in its results.

The number of the moduli is the subject of the first two papers. In the earlier of the two [1] he remarks that Riemann, by analysis, found

[1] *Math. Ann.*, vol. i., pp. 401–406, 1869, 'Note bezüglich der Zahl der Moduln einer Classe von algebraischen Gleichungen.'

$3p-3$ to be the number of moduli of his 'normal' function, whereas Cayley [1] obtained, by geometrical considerations, the number $4p-6$ for the curve of $(p+1)$th order, the 'normal' curve of Clebsch and Gordan; but by actually performing the transformation of the latter—in the case $p=4$—into Riemann's form, Brill shows that there are in fact only $3p-3$ moduli (a result which Cayley verified later.) [2] The second paper [3] was occasioned by a memoir by Casorati and Cremona,[4] in which the transformation of Clebsch and Gordan's form into Riemann's is effected, by geometrical methods, for the cases $p=4$, 5, 6. Brill obtains their results by different methods, employing the properties of curves in space of three dimensions. An example for $p=6$ is a septic with nine double points; this he connects by a one-one transformation with a curve in space of the 8th degree, quoting Cayley [5] to show that the transformation can be effected in exactly five ways, corresponding to the five straight lines in space which meet the tortuous curve of the 8th degree in four points. Similarly for $p=7$, the transformation of a plane curve of the 8th degree can be effected in twenty-one different ways. These examples are important, as forming a connecting link between the theory of transformation, in which they presented themselves, and the theory of elimination, to which they directly lead; moreover, within the theory of elimination they suggest the question of the number of different solutions satisfying a system of simultaneous equations.

In the year 1871, Brill begins to turn his attention to a wider theory, that of elimination when stated algebraically, or of correspondences when stated geometrically. This is shown in the title of a paper,[6] which contains proof of theorems required in the succeeding paper; [7] but neither of these has any immediate application to our present purpose.

The geometrical side of the theory of correspondences had been already attacked by Chasles, De Jonquières, and Cayley, but algebraical proofs of many theorems were still wanting; and, moreover, the treatment of the problems in a purely symbolical and analytical manner led to the establishment of theorems in the general theory of elimination, which in their turn apply to a region intimately connected with the theory of correspondences—that of point-groups on a curve—but at the date we speak of, still comparatively unexplored.

In Brill's first important contribution to the theory of elimination,[8] he attacks the problem of the number of different solutions which satisfy a system of simultaneous equations.[9] He remarks that Roberts [10] and Salmon [11] confined themselves to a discussion of the degree of the eliminant in the whole number of variables, not the degree in which

[1] *Proc. London Math. Soc.*, vol. i., 1865, 'On the transformation of plane curves.'

[2] *Math. Ann.*, vol. viii., pp. 359–362. 'On the group of points G_4^1 on a sextic curve with five double points,' 1874.

[3] *Ibid.*, vol. ii., pp. 471–474, 1870, 'Zweite Note bezüglich der Moduln einer Classe von algebraischen Gleichungen.'

[4] *Accad. Milan*, May, 1870.

[5] *Phil. Trans.*, 1870, 'On skew surfaces.'

[6] *Math. Ann.*, vol. iv., pp. 510–526, 'Zur Theorie der Elimination und der algebraischen Curven.'

[7] *Ibid.*, pp. 527–549, 'Ueber zwei Berührungsprobleme.'

[8] *Math. Ann.*, vol. v., pp. 378–396, 1872, 'Ueber Elimination aus einem gewissen System von Gleichungen.'

[9] See also *Math. Ann.*, vol. iv., pp. 542–548, 1871.

[10] Crelle, vol. lxvii., pp. 266–278, 1867.

[11] *Higher Algebra*, Lessons VIII. and XVIII.

each variable appears. The latter is the more difficult problem, and admits of complications in which the interpretation of certain equations as correspondences is of great value (see *infra*, p. 129).

In this paper he finds by induction, without a rigorous proof, a formula for the number of solutions of a system of equations in k independent variables (each equation being symmetrical in all the variables), the system consisting of a number of equations equivalent to $i+1$ independent equations; so that $k-i-1$ of the variables must have arbitrarily assigned values before the expression 'number of solutions' can have a meaning. When $k-i-1$ have been so chosen, the 'number of solutions' means the number of different ways in which the remaining $i+1$ can be found to satisfy any $i+1$ equations of the system. The number (see formula (A), *infra*) is made to depend on the sums and differences of the numbers of common solutions of pairs of systems of equations (in square brackets in (A) below), one system of each pair being of the same kind as the original system, but equivalent to fewer than $i+1$ independent equations; while the second system of the pair is either precisely one equation, symmetrical in all the variables, or consists of a system equivalent to 2, or 3, . . ., or $i+1$ independent equations, involving only $k-1$, $k-2$, . $k-i$ variables respectively. As an important example of a system of equations of the assumed nature, he considers the original system to consist of all the equations formed by equating to zero every k-rowed determinant of the following matrix of $k+i$ columns and k rows,

$$\left\|\begin{matrix}\phi_1(\lambda_1), & \phi_2(\lambda_1), & \dots & \phi_{k+i}(\lambda_1)\\ \phi_1(\lambda_2), & \phi_2(\lambda_2), & \dots & \phi_{k+i}(\lambda_2)\\ \vdots & & & \\ \phi_1(\lambda_k), & \phi_2(\lambda_k), & \dots & \phi_{k+i}(\lambda_k)\end{matrix}\right\|$$

where $\phi_1, \dots \phi_{k+i}$ are integral functions of the mth degree of the single variables enclosed in the brackets, these variables $\lambda_1, \dots \lambda_k$ being all independent. Such a matrix is more shortly written as $\|k+i\|_k$, and the number of solutions as $(k+i)_k$. This notation is also employed when the ϕ's are functions of more than one variable each, the variables being then connected by k relations (see *infra*, p. 127). The number of common solutions of all the k-rowed determinants it contains is known to be equal to the number of common solutions of the $i+1$ determinants,

$$\begin{vmatrix}\phi_1(\lambda_1), & \dots & \phi_{k-1}(\lambda_1), & \phi_t(\lambda_1)\\ \vdots & & \phi_{k-1}(\lambda_2), & \phi_t(\lambda_2)\\ \phi_1(\lambda_k), & \dots & \phi_{k-1}(\lambda_k), & \phi_t(\lambda_k)\end{vmatrix}$$

where $t=k, k+1, \dots k+i$ in turn, provided the $k-1$-rowed determinants of the matrix

$$\left\|\begin{matrix}\phi_1(\lambda_1), & \dots & \phi_{k-1}(\lambda_1)\\ \vdots & & \vdots\\ \phi_1(\lambda_k), & \dots & \phi_{k-1}(\lambda_k)\end{matrix}\right\|$$

do not all vanish.

By a generalisation of simple cases, this number of solutions is reduced to the following formula :—

$$\text{(A)}\qquad (k+i)_k=[(k+i-1)_k(k)_k]-[(k+i-2)_k(k-1)_k]+\ \dots \\ \dots\ \mp[(k)_k\,(k-i+1)_k]\pm(k-i)_k$$

where $[(k+i-1)_k\,(k)_k]$ stands for the number of common solutions of $\|k+i-1\|_k$ (equivalent to i independent equations, provided the $k-1$-rowed determinants, mentioned above, do not vanish), and of $\|k\|_k$ which represents precisely one equation ; and so on. A rigorous proof of this formula was not given until 1890,[1] but, assuming it to hold, the number of solutions, when the variables are all independent, is found by perfectly valid reasoning in the paper under consideration, and particular cases of the more general problem, to which formula (A) also applies (*i.e.* when there are k pairs of variables, connected by k relations), are solved in the next paper [2] by direct evaluation.

When the terms of the right-hand side of (A) come to be actually evaluated, the particular case, here alone considered (*i.e.* of k independent variables), proves capable of direct treatment by algebraic theorems in elimination proved in the earlier part of the paper, and the final result is

$$(k+i)_k=\frac{(m-k+1)\,(m-k)\ \dots\ (m-k-i+1)}{1\ .\ 2\ .\ 3\ \dots\ i+1}$$

From the point of view of the theory of point-groups, a geometrical problem which Brill solves by means of formula (A) is of interest ; it is thus stated :

Given a $(k+i-1)$-ply infinite family of curves of order m, viz. : $a_1\phi_1(x,y)+a_2\phi_2(x,y)+\ \dots\ +a_{k+i}\phi_{k+i}(x,y)=0$. Assuming $k-i-1$ *of the points of intersection with a straight line, to find* i *others such that every curve through these* $k-1$ *also passes through a certain* k*th point. In how many ways can this be done?*

Or, in other words :

In how many ways can k *points be chosen on a straight line, so that an* i*-ply infinite system of curves, selected from a* $(k+i-1)$*-ply infinite system may pass through them?*

Since the number of solutions is all that is required, the problem is not made less general by taking the intersections with a definite straight line, say $y=0$; substituting this value for y in the equation from the outset, we are led to finding the number of solutions of exactly the matrix considered on p. 125, leading to formula (A), which, since $x_1,\ \dots\ x_k$ are k independent variables, can be directly evaluated as above.

Brill's investigations into the theory of correspondences definitely commenced in 1872.[3] In the introductory remarks he attributes the origin of this theory (in geometry) to Chasles, who, in 1864, first enunciated the principle of correspondence for points on a straight line : '*if to every point* x *there are* n *points* y, *and to every point* y *there are* m *points* x, *then at* m+n *points an* x *coincides with a* y ;' and who afterwards extended it, in 1866, to points on any unicursal curve.[4] Cayley

[1] *Math. Ann.*, vol. xxxvi., p. 326. [2] *Ibid.*, vol. vi.

[3] *Ibid.*, vol. vi., pp. 33–65, 'Ueber Entsprechen von Punktsystemen auf einer Curve.'

[4] *Comptes Rendus*, vol. lviii., June 27, 1864, and vol. lxii., p. 11.

had given[1] an extension of this principle to curves of any deficiency p,[2] without, however, formally proving it, and it is at this stage that Brill took up the subject. He gives an algebraic proof of Cayley's formula for the number of *united points* of one correspondence on a given curve of deficiency p, and he finds, moreover, the proper extension to curves of any deficiency of the well-known algebraic theorem: '*if between the points* x, y *of a straight line, there exists a relation* $\phi(\mathrm{x}, \mathrm{y})=0$ *by means of which* κ *points* x *correspond to a point* y *and* λ *points* y *to a point* x; *and further, if by means of a second relation* $\phi'(\mathrm{x}, \mathrm{y})=0$ κ' *points* x *correspond to* λ' *points* y; *then the number of pairs of points which satisfy both relations is* $(\phi\phi')=\kappa\lambda'+\kappa'\lambda$.' The first relation $\phi(x, y)=0$ is said to establish a correspondence (κ, λ) between the points on the straight line; the second, $\phi'(x, y)=0$, a correspondence (κ', λ'), and $(\phi\phi')$ gives the number of pairs of points which satisfy both correspondences.

Brill's extension is as follows:—*Given a fixed point* z *on a curve* f *of deficiency* p, *and two movable points*, x, y, *on the same curve, and let the two relations*, $\phi(\mathrm{x}, \mathrm{y}, \mathrm{z})=0$, $\phi'(\mathrm{x}, \mathrm{y}, \mathrm{z})=0$ *hold, which, regarded as functions of* x *have* k, k′ *points of intersection, respectively, with* $\mathrm{f}(\mathrm{x})=0$, *of which* β, β', *respectively, coincide with the point* z, *and* γ, γ' *with the point* y;[3] *and which, regarded as functions of* y, *have* l, l′ *points of intersection, respectively, with* $\mathrm{f}(\mathrm{y})=0$, *of which* α, α', *respectively, coincide with the point* z, *and* γ, γ' *with the point* x; *then the number of pairs of points*, x, y, (*each point being distinct from the other and not coinciding with* z), *which satisfy both relations is given by* $(\phi\phi')=\kappa\lambda'+\kappa'\lambda-2p\gamma\gamma'$,

$$\text{where } \begin{cases} \kappa=k-\beta-\gamma, \ \kappa'=k'-\beta'-\gamma' \\ \lambda=l-\gamma-\alpha, \ \lambda'=l'-\gamma'-\alpha'. \end{cases}$$

The first application of this formula is *to find in how many ways three points on a curve* $\mathrm{f}=0$ *can be chosen, so that a singly infinite system of curves, selected from a given triply-infinite system, may pass through them.* This is a simple case of the problem already referred to on p. 125 (viz. $k=3$, $i=1$), but now we have to deal with a base-curve of any deficiency p, instead of the straight line, and thus it is impossible to eliminate y and to obtain equations in three independent variables x_1, x_2, x_3. We obtain a matrix similar, but not identical, to that on p. 125, viz.:—

$$\left\|\begin{matrix} \phi_1(x_1y_1), & \phi_2(x_1y_1), & \phi_3(x_1y_1), & \phi_4(x_1y_1) \\ \phi_1(x_2y_2), & \phi_2(x_2y_2), & \phi_3(x_2y_2), & \phi_4(x_2y_2) \\ \phi_1(x_3y_3), & \phi_2(x_3y_3), & \phi_3(x_3y_3), & \phi_4(x_3y_3) \end{matrix}\right\|$$

and further, the three equations $f(x_1y_1)=0$, $f(x_2y_2)=0$, $f(x_3y_3)=0$.

As before remarked, however, the formula (A) still holds and gives us $(3+1)_3=[(3)_3(3)_3]-(3-1)_3$ but for this simple case it is worth while to work out the problem directly in the first place, without using formula (A), as it affords insight into the geometrical meaning of a correspondence

Observe, first, that before a finite number of solutions can be found, one point, z, on $f=0$, must be assumed arbitrarily, since $k-i-1=1$.

[1] *Comptes Rendus*, vol. lxii., 1866, p. 586.

[2] Cayley's result is that the number of 'united points' is $m+n+2pk$, where k is a quantity afterwards known as the *Wertigkeit* of the correspondence curve.

[3] β is said to be the *Wertigkeit* of ϕ at $x=z$, γ at $x=y$;
β' " " " " ϕ' at $x=z$, γ' at $x=y$;
α " " " " ϕ at $y=z$,
α' " " " " ϕ' at $y=z$.

Also, if any two independent curves of the triply-infinite system can be passed through this arbitrary point z and through certain other two x, y, on $f=0$, then a singly-infinite number passes through these three points, and they form one of the triplets whose number is required. To arrive at two independent curves of the system, take any two fixed points A, B, in the plane, and consider first the curve through z and A, then that through z and B; each has still one degree of freedom, but loses this and becomes perfectly determinate if passed through a common point y on $f=0$. Let every curve of the triply-infinite system have M movable points of intersection with $f=0$—that is to say, M points whose co-ordinates depend on the variable parameters of the system—then these two independent curves determined by y have each $M-2$ points of intersection x with $f=0$ besides z and y; and in general the $M-2$ x's belonging to one curve will be all distinct from those belonging to the other; but if y be properly chosen (or, we may say, for certain positions of y on $f=0$) an x of one curve will coincide with an x of the other, x, y, z thus forming one of the required triplets, since two independent curves pass through them. The expression *for certain positions of* y *on* f=0 introduces the idea of the movement of the point y on f, which necessitates a corresponding movement of the two sets of $M-2$ x's belonging to the two distinct curves; we may say with reference to each curve, that to every position of y there correspond $M-2$ positions of x; moreover, since, when confining the attention to the curve through z and A, it is immaterial which of the $M-1$ points is called y, we say that to every position of x there correspond $M-2$ positions of y: *we have a symmetrical correspondence* $(M-2, M-2)$ *between the points* x, y *established on* f=0 *by means of the curve through* z *and* A; and, similarly, we have another established by means of the curve through z and B. But we have already pointed out that for certain positions of y, *i.e.* of the one of the $M-1$ points which is common to both curves, there will be an x common to them as well, and it is the number of such positions of y (or of this x, since the relation of this particular x and y is reversible) that we wish to find.

Again, since the original system has three degrees of freedom, the system through A (or through B) has two degrees of freedom; hence one curve of the system can always be drawn to touch $f=0$ at any point on it, and no curve can have a double point. In other words, wherever z is taken on $f=0$, there is always one position of y which coincides with z (on the curve touching $f=0$ at z), or $y=z$ satisfies the correspondence equation ϕ identically once. (If no curve could have been drawn to touch $f=0$ at any arbitrary point, $y=z$ would not satisfy the correspondence equation identically at all, whereas, if a curve with a double point at any arbitrary point on $f=0$ could have been drawn, then $y=z$ would have satisfied the correspondence equation identically twice, &c.) The number of times that $y=z$ satisfies the correspondence equation is called the 'Wertigkeit' of the correspondence, and is denoted by $[\phi]_{yz}$. In symmetrical correspondences, such as the one above, x, y, z are all interchangeable, and therefore $[\phi]_{xy}=[\phi]_{xz}=[\phi]_{zy}$.

The value of the 'Wertigkeit' is written as a subscript to the bracket $(\phi\phi')$; thus, in the language of correspondences, the number of solutions to our present problem is the number of pairs of points which satisfy two correspondence equations, each given as $(M-2, M-2)_1$. But from this number must be subtracted those pairs of points which lie on that one curve of the triply-infinite system which passes through both A and B as well as z, for these do not lie on two distinct curves, and therefore not on a curve

of a singly-infinite system. The number of such pairs is obviously the combinations in twos of the $M-1$ points besides z, which lie on $f=0$, *i.e.* it is $\dfrac{M-1 . M-2}{2}$. If, therefore, we write $\kappa=\kappa'=\lambda=\lambda'=M-2$ and $\gamma=\gamma'=1$ in the formula given on p. 127 for $(\phi\phi')$ (dividing it, however, by 2, since our correspondences are symmetrical), and then subtract $\dfrac{M-1 . M-2}{2}$ from this, we obtain the number of triplets, viz. $(M-2)^2-p-\frac{1}{2}(M-1)(M-2)=\frac{1}{2}(M-2)(M-3)-p$.

Now compare the steps of this process with the formula (A) for this case, *i.e.* with $(3+1)_3=[(3)_3(3)_3]-(3-1)_3$ and we see that the two correspondences employed, exactly similar, were the determinants, the number of whose solutions was denoted by $(3)_3$, $(3)_3$, while $(3-1)_3$ gives the number of those solutions which needed to be subtracted from the total number.

In more complicated problems, formula (A) is used at once, and the evaluation of the number of common solutions of the equations in the square brackets (the number and form of these equations is given above, pp. 125 and 126) is performed by interpreting *these* as correspondence equations (cf. p. 124), provided we know how many points correspond to one in each correspondence (they are always symmetrical, as is seen at once from the form of the determinant) and also the 'Wertigkeit' of the points $x=y$, &c. (Here again, by symmetry $[\phi]_{xy}=[\phi]_{yz}=\ldots$ &c., for the determinant will vanish identically exactly the same number of times whichever rows are made the same.)

The other cases to which Brill applies the theory of correspondences in the paper under consideration are :—

(*a*) *To find the number of triplets of points on a given base-curve through which a doubly-infinite system of curves, contained within a 4-ply infinite system, can be made to pass.*

(*b*) *To find the number of sets of four points on a given base-curve through which a triply-infinite system of curves, contained within a 6-ply infinite system, can be made to pass.*

In the first of these $k=3$, $i=2$; in the second $k=4$, $i=3$. They are both rather more complicated than the one we have considered in detail; the first, namely, involves finding the number of triplets of points which satisfy three correspondences, for

$$(3+2)_3=[(3+1)_3(3)_3]-[(3)_3(2)_3]+(1)_3,$$

and the number of independent equations (see p. 126) involved in $[\|3+1\|_3, \|3\|]$ is $2+1=3$, involved in $[\|3\|_3, \|2\|_3]$ is $1+2=3$, and involved in $(1)_3$ is 3; similarly, the second involves finding the number of sets of 4 points which satisfy 4 correspondences, for here we have

$$(4+3)_4=[(6)_4(4)_4]-[(5)_4(3)_4]+[(4)_4(2)_4]-(1)_4,$$

and the total number of independent equations in each term of this expression is 4, namely, $3+1$, $2+2$, $1+3$ and 4. Moreover, it is essential to the final evaluation to take notice of the way in which the 4 independent equations are grouped; the formulæ in the theory of correspondences for finding the number of sets of 4 points which satisfy 4 equations when these 4 are grouped as $3+1$ differs from that in which they are grouped as $2+2$; but since the difference only appears in the terms

involving p, it does not exist when $p=0$, *i.e.* when the base-curve is a straight line or a unicursal curve, and it was for this reason that the actual solution of the previous problem (p. 126) was possible. The required formulæ for $i=1, 2, 3$ (leading to 2, 3, and 4 simultaneous correspondences), are worked out in the earlier part of this paper for all possible different groupings of the sets, and the final results for examples (*a*) and (*b*) are

$$(a)\quad \frac{M-2.M-3.M-4}{1.2.3}-p\,(M-4)$$

$$(b)\quad \frac{M-3.M-4.M-5.M-6}{1.2.3.4}-\frac{M-6.M-5}{1.2}.p+\frac{p(p-1)}{2}$$

where, as before, M denotes the number of movable points of intersection of each curve of the given system with $f=0$. We notice in passing that these results agree with that of p. 126, when $p=0$, $M=m$.

A problem in the theory of point-groups, of which the above are particular cases, was first enunciated in the most general form in a paper by Brill and Noether, in 1873.[1] They state it thus :—

Given a t*-ply infinite system of adjoint curves—that is, of curves passing* s—1 *times through every* s*-fold point of* f=0—*it is required to find R points on the base-curve,* f=0, *which form such a point-group—or set of points—that the curves of the given system which pass through it form a* q*-ply infinite system.* If the equation of the system is

$$a_1\phi_1(x_1y)+a_2\phi_2(xy)+\quad .\quad .\quad .\quad +\phi_{t+1}\phi_{t+1}(x_1y)=0$$

this problem leads, by known theorems, to finding the common solutions of all the $(t-q+1)$ rowed determinants of the matrix.

$$\left\|\begin{matrix}\phi_1(x_1y_1), & \phi_2(x_1y_1), & . & . & . & \phi_{t+1}(x_1y_1)\\ \phi_1(x_2y_2), & . & . & . & . & \phi_{t+1}(x_2y_2)\\ \vdots & & & & & \\ \phi_1(x_Ry_R), & . & . & . & . & \phi_{t+1}(x_Ry_R)\end{matrix}\right\|$$

where

$$x_1y_1,\ x_2y_2,\quad .\quad .\quad .\quad .\quad .\quad x_Ry_R,$$

are connected by the equations

$$f(x_1y_1)=0,\quad .\quad .\quad .\quad .\quad .\quad f(x_Ry_R)=0.$$

The simplest case is therefore to be found by taking $R=t-q+1$, and this is, in fact, the only case completely solved. The formula for the number of solutions was given in this memoir, viz. :—

$$(B)\qquad (R+q)_R=\binom{Q+1}{q+1}-\binom{p}{1}\binom{Q-1}{q-1}+\binom{p}{2}\binom{Q-3}{q-3}-\quad .\quad .\quad .$$

$$.\quad .\quad .\quad +\begin{cases}(-)^{\frac{q}{2}}\binom{p}{\frac{1}{2}q}\binom{Q+1-q}{1}\quad .\quad .\quad .\quad .\quad i\text{ even}\\ (-)^{\frac{q+1}{2}}\binom{p}{\frac{1}{2}(q+1)}\quad .\quad .\quad .\quad .\quad .\quad i\text{ odd}\end{cases}$$

[1] *Math. Ann.* vol. vii., pp. 269–310. 'Ueber die algebraischen Functionen und ihre Anwendung in der Geometrie.'

where $Q=2p-2-R$ and $\binom{l}{m}$ stands for $\frac{l(l-1) \quad . \quad . \quad . \quad (l-m+1)}{1.\ 2 \quad . \quad . \quad . \quad m}$

but the rigorous proof only appeared in the year 1890. For particular values of q, however, viz. $q=1, 2, 3$, and assuming the rigorous proof of formula (A), formula (B) was proved in the previous papers. In fact, we see that (a) and (b) on p. 130 are particular instances in which $R=k$, $q=i$, $Q=M-k$.

Report on the Chemical Compounds contained in Alloys. *By* F. H. Neville, *F.R.S.*

PART I.

PART II.

PART I.

Although most students of alloys are now convinced that they often contain definite chemical compounds, yet these 'intermetallic' compounds are still passed over in silence by the authors of books on descriptive chemistry. The cause of this omission lies in the difficulty of isolating these bodies in a pure state, and in their resemblance to the metals. It must be acknowledged that just as the metals resemble one another more than do the non-metals, so their compounds often present a great superficial resemblance to their constituent elements. Intermetallic compounds might well be compared to the somewhat intangible bodies formed by the union of the halogens with each other and with sulphur. Many of these bodies show marked dissociation—that is to say, they readily form systems in true equilibrium with their components; it is almost certain that 'intermetallic' compounds present the same phenomenon when in contact with liquid alloy.

Methods of Studying Intermetallic Compounds.

The method that naturally suggests itself to a chemist is that of extracting the pure compounds from an alloy by filtration, by volatilisation of excess of a volatile metal, or by removing the excess of metal by means of a suitable solvent. Each of these methods has been employed with some success.

Filtration methods are very difficult at high temperatures, but if the difficulties can be overcome so that the first solid separating from a liquid as it freezes is isolated, we shall get invaluable information. By the filtration of a partly solidified solution of gold and cadmium in tin, Heycock and Neville ([1]) obtained a crystalline residue approximating to the formula

AuCd, even when the proportions of gold and cadmium in the original mixture varied within wide limits. Again (2), by alloying gold with excess of cadmium and distilling off the excess of cadmium they obtained a residue having the composition AuCd. Now that many metals have been distilled *in vacuo* this method may meet with success in other cases.

M. Lebeau (3) dissolves metals in excess of sodium and distils off the excess of sodium by the prolonged passage of ammonia gas followed by that of nitrogen. He thus obtains the bodies $SbNa_3$, $BiNa_3$, $SnNa_4$ in a pure state. He is also succeeding by the same method with the other alkali metals. M. Joannis (4) some years ago applied a similar method successfully.

The method of fractional solution enabled Debray (5) to isolate the bodies $PtSn_4$, $RhSn_3$, $RuSn_3$, by the action of dilute hydrochloric acid on alloys containing excess of tin. M. Le Chatelier (6) has in the same way isolated the compound Cu_3Sn. He emphasises the opinion that by choosing a suitable solvent, suggested by electro-chemical considerations, the method will be found generally applicable. For example, by subjecting alloys of copper and zinc to the prolonged action of a paste of lead chloride he has obtained crystals of pure Zn_2Cu. Mr. Heycock, in a research not yet published, obtained large crystalline grains of $PtAl_3$ by the action of hydrochloric acid on a slowly cooled alloy of aluminium and platinum. Mr. Stead (7) has isolated in this way crystals of SnSb, Au_4Pb, Au_5Pb_2, Sn_3As_2, and probably of some other alloys. The work is in some cases not yet published, but he has been kind enough to communicate the results for the purpose of this report.

Other cases could no doubt be quoted in which fractional solution leaves a residue having a formula, but there is a great risk of the solvent attacking the crystals ; and, as Mr. Stead has found, the existence of mixed crystals, or, at all events, of crystals having a core different from the outside, is a serious drawback to this method regarded as an independent method of discovery. It would seem that the proper moment for the application of these methods comes when by the microscope, by the freezing-point curve, or by potential determinations the existence of a compound has been already indicated.

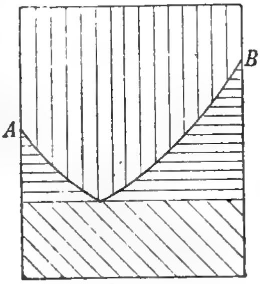
In a systematic study of intermetallic compounds I should therefore put first that of the chemical equilibrium of the binary system : this is generally expressed by the freezing-point curve. Next, and perhaps of equal importance, comes the microscopic examination of the solid alloys. Thirdly, as more limited in scope, but sometimes more emphatic in its indications, comes the determination of the difference of electrical potential existing between a metal and its alloys.

The method of studying chemical equilibrium which we owe so largely to Professors Bakhuis Roozeboom and Le Chatelier is now familiar to most chemists, and in the case of a binary system it can be sufficiently described in a few words. A mixture of two substances, A and B, in certain proportions is melted. It is allowed to cool slowly, and the temperature is noted at which solid matter begins to separate from the liquid. This is the 'freezing-point.' It tells us the temperature at which this particular mixture becomes saturated—that is to say, comes into equilibrium with a particular solid. By repeating the experiment with a series of mixtures of A and B we get as many points as we need for plotting the freezing-point curve. In this curve, one ordinate is the percentage composition of the mixture expressed either in weight per cent. of A and B, or, better, in atomic or molecular

per cents. ; the other ordinate is temperature. It is desirable to observe not only the first halt in the cooling, but also any lower ones that occur down to the moment of complete solidification, or even below it. It is also desirable to isolate by filtration the crystals which form at the freezing-point, and to analyse them. This would give the composition of the solid and liquid phases which could exist in equilibrium at the observed temperature. Unfortunately, on account of experimental difficulties, isolation of the solid phase has not been carried out in the case of alloys, and a later microscopic study of the wholly solid alloy is a very imperfect substitute for it.

We now know pretty well the types of freezing-point or equilibrium curves that occur. In the simplest of all cases—that in which the two bodies A and B neither combine chemically nor form mixed crystals—the complete curve resembles fig. 1. It consists of two branches cutting each other at the eutectic angle. One branch, which starts from the freezing-point of a liquid wholly composed of A, corresponds to the formation of primary crystals of pure A at each freezing-point, the other branch to the formation of primary crystals of pure B. When the liquid, either from its initial composition or through the separation of the primary crystals, reaches the composition of the eutectic intersection, A and B crystallise simultaneously but in separate crystals. Thus the solid eutectic alloy is a very minute conglomerate, while all other alloys contain large primary crystals of either A or B embedded in this conglomerate. This has been conclusively demonstrated by the exquisite microscopic work of M. Osmond (8) and also by that of M. Charpy (9).

FIG. 1.



Curves which approximate to this type have been worked (10 and 11) out for the pairs Zn.Al, Zn.Sn, Au.Cu, Ag.Cu, and some other metals. Such curves do not indicate the existence of a compound, though it would be too much to say that they disprove the existence of compounds.

When a compound exists whose melting-point lies in the region above the freezing-point curve of the two metals, it produces a separate branch cutting the other two branches. At points on this intermediate branch the saturated liquid deposits crystals of the compound. The summit of this branch occurs at the concentration corresponding to the formula of the compound. If more than one compound exists there is a branch for each compound, although parts of the branches may be lost by lying below the curves of more stable bodies.

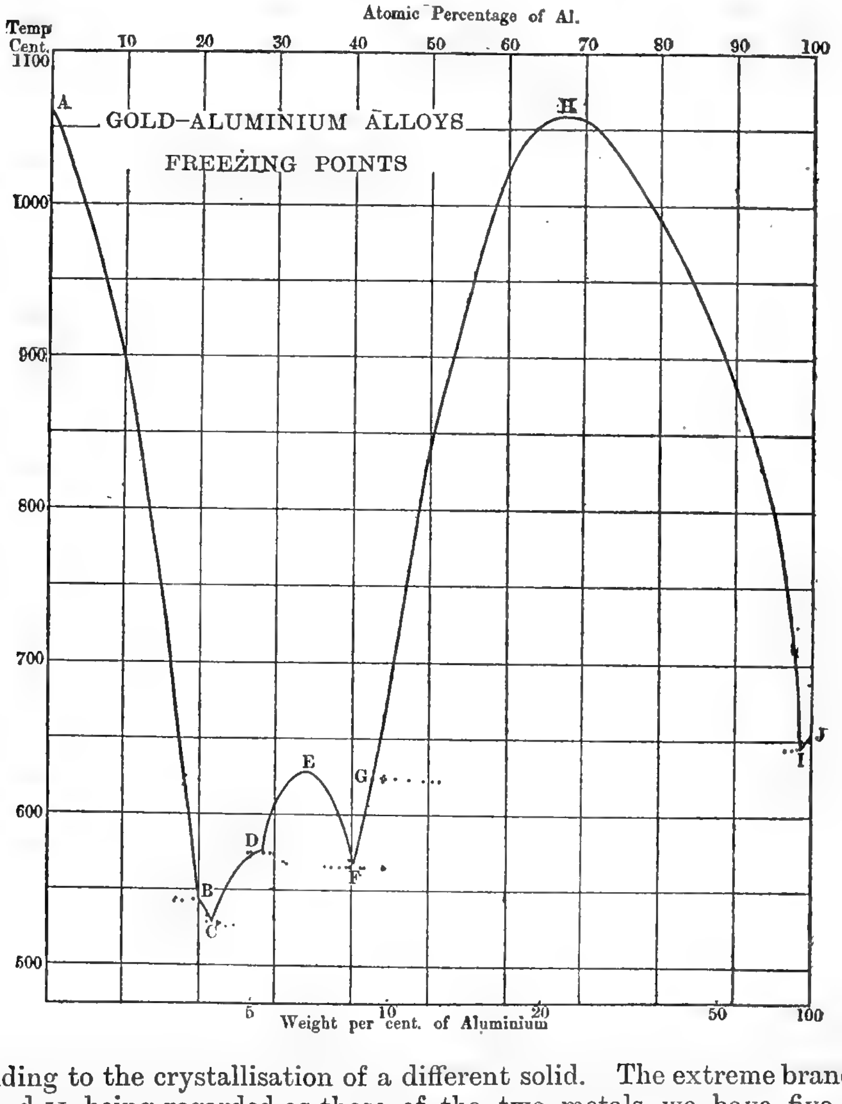
While the above is the usually accepted view as to the meaning of summits and eutectic angles in a freezing-point curve, two points may be noted. The first is M. Le Chatelier's opinion as to the position of the summit caused by a compound. He thinks (12) that when a compound partly dissociates on fusion, the summit caused by its presence may not be exactly at the percentage composition corresponding to its formula, and that the formation of mixed crystals may have a similar effect on the curve. This is a matter needing further investigation. The other point concerns the position of the eutectic angle. While it is well established that the eutectic alloy is a conglomerate, not a compound, we should be wrong to ignore the fact that the angle often comes surprisingly near to

a simple formula—for example, in the AgCu and AuCu curves. Sir George Stokes has lately recalled our attention to this point. Paterno and Ampolla ([13]) have noticed a number of similar cases in organic mixtures.

A good many curves indicating by intermediate branches the existence of compounds have now been determined, but for the purpose of illustrating the subject further the curve of AuAl will be taken.

As can be seen from fig. 2, there are seven branches, each corre-

FIG. 2.

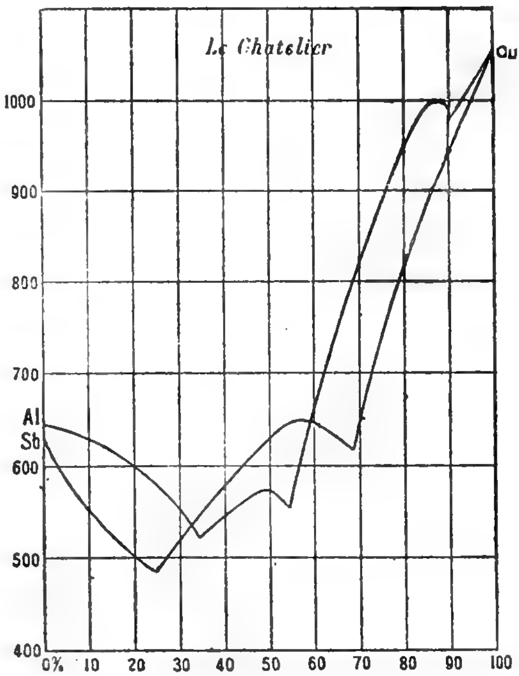


sponding to the crystallisation of a different solid. The extreme branches, AB and IJ, being regarded as those of the two metals, we have five left, each of which *may* indicate a compound. The branch DEF has its summit exactly at the formula Au_2Al. The microscope shows that the summit alloy E is an almost homogeneous body, and that all solid alloys whose composition lies between that of D and F contain large crystals of the E body immersed in a mother substance. As we descend the curve from the summit the large crystals of E are found to occupy less and less of the whole alloy, until at D and F they cease to exist. Exactly similar

phenomena show themselves on the branch GHI ; the summit H occurs at the formula $AuAl_2$, and large crystals of this body are found embedded in mother substance in all alloys between G and I.

These criteria taken together—(1) the occurrence of a summit at a formula percentage, (2) the presence of large crystals of the same kind, decreasing in amount as we descend the branch on either side—are, I believe, an absolute proof of the reality of a compound. The two bodies Au_2Al and $AuAl_2$ as certainly exist as do the two chlorides of copper. But there are other compounds more obscurely indicated by the curve ; the branch FG has its summit, X, below the branch GH, hence the X body which crystallises at points on GF never occurs alone in a solid alloy. The microscope shows that solid alloys between G and H contain large crystals of $AuAl_2$, surrounded by a coating of the X body, and that outside this coating there are large independent crystals of X embedded in a minute conglomerate of X and E. The fact is that in the first stage of freezing, while the large crystals of $AuAl_2$, or H, are forming, the liquid part necessarily gets richer in gold until it reaches the composition G. From this moment the H crystals cease to form, and the existing ones become coated with the X body, which at lower temperatures crystallises independently in large crystals, that in a certain sense are primary. Finally, the residual liquid reaches the state F, and the eutectic conglomerate forms which is composed of crystals of Au_2Al and of X. Thus an alloy may contain a compound although that compound does not occur as the sole constituent of any particular alloy. This appears to be a very common case ; for example, Mr. Stead finds that in bronzes very rich in tin the crystals of Cu_3Sn are coated with CuSn, and M. Charpy (9) has recorded a similar feature in the bronzes very rich in copper. In both these cases the eutectic lies outside the coating.

FIG. 3.



MM. Le Chatelier (14), Gautier, and Gosselin (10) have traced a number of remarkable freezing-point curves for pairs of metals, of which examples are given here. Unfortunately the composition is stated in percentage by weight, not in atomic per cents.

Copper-Aluminium (fig. 3).—Here we find two well-marked summits, one very exactly at Cu_3Al, the other near $CuAl_2$.

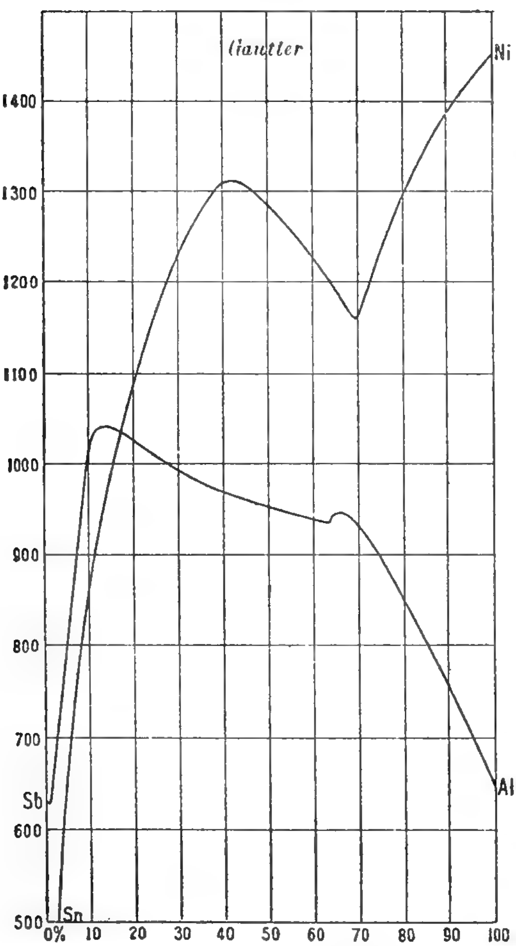
Copper-Antimony (fig. 3).—Here there is a well-marked intermediate summit which, if it were at a formula point, would almost certainly indicate a compound. M. Le Chatelier attributes the formula Cu_2Sb to it, but measurement on the curve seems to give the summit the formula Cu_5Sb_2. These two curves, and one of SnCu also due to M. Le Chatelier,

are especially interesting, as they were the first high-temperature curves of this kind with intermediate summits due to compounds that had been published, and the paper (14) in which they appeared marks a new departure in the subject of alloys.

Aluminium-Antimony (fig. 4).—The maximum point is very much higher than that of either metal; it is at 1048° C. with 14·66 per cent. of aluminium. The curve is remarkable because it shows that nearly all mixtures melt above the melting-point of either component.

Nickel-Tin (fig. 4).—Here the intermediate summit is at Ni_3Sn_2.

FIG. 4.



M. Gautier gives other curves of great interest, some of which were simultaneously studied by Heycock and Neville (11), but many of them need further work before they can be safely interpreted.

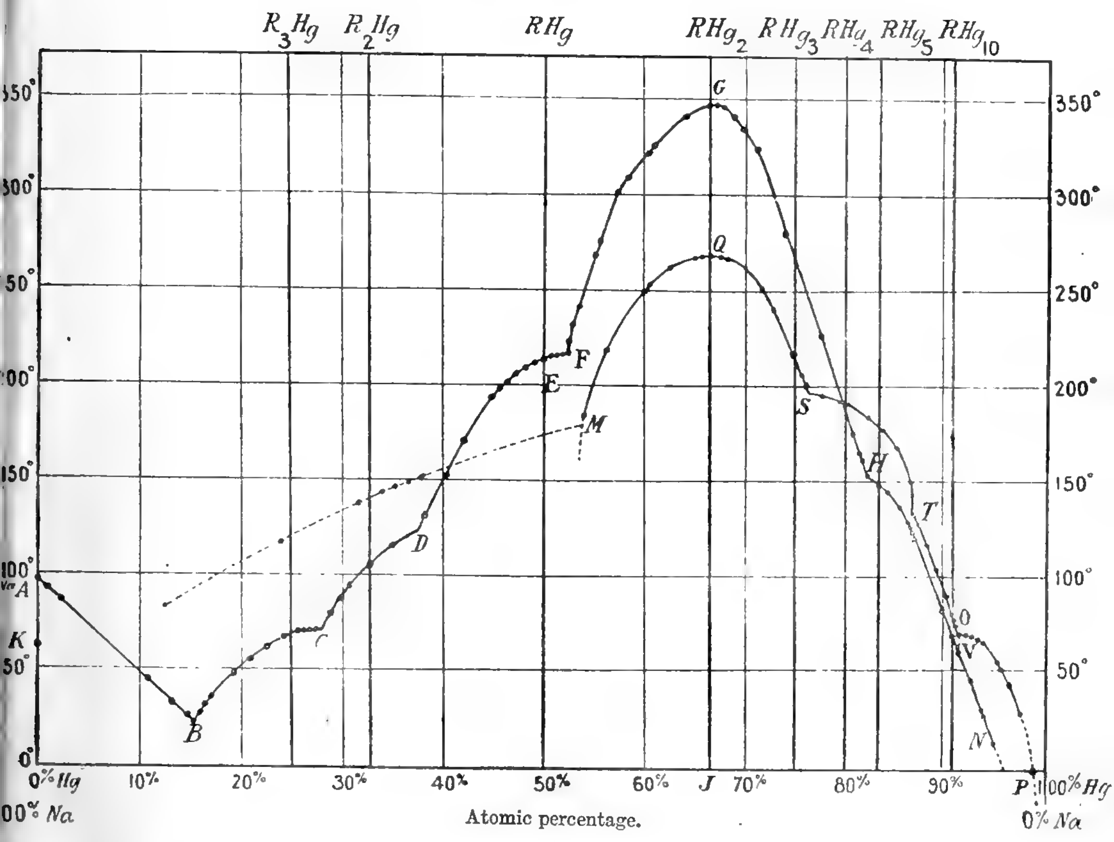
Perhaps the freezing-point curves investigated by M. Kurnakov throw as clear a light on intermetallic compounds as any work that has been done. This work can be readily followed from the two diagrams contained in his paper, and reproduced in figs. 5 and 6. The composition is expressed in atomic percentages. The first diagram (fig. 5) gives the freezing-point curves of amalgams of sodium and potassium. In the HgNa curve at least six separate branches can be seen, each corresponding to the crystallisation of a different solid. It would be premature to assert that each branch proves the existence of a corresponding chemical compound, but there can be no doubt that the summit G proves the existence of the compound $NaHg_2$, a body whose melting-point is much higher than that of either component. Similarly, in the curve for potassium amalgams, besides minor branches there is a well-marked summit at the formula KHg_2.

The other figure (fig. 6) gives the freezing-point curves of the mixtures NaBi, NaPb, NaCd. It is unfortunate that so few alloys were examined on the upper part of the NaBi curve, but the existence of the freezing-point M above 700° C. makes a compound very probable. M. Kurnakov seems to have no doubt that it indicates Na_3Bi, a body already prepared by Joannis and by Lebeau. There are two summits on the NaPb curve—one at P, which must be very near the formula Na_2Pb and one at P′ to which he does not at present assign a formula. In the NaCd curve we

see two well-marked summits, at O and O′, the first being exactly at the formula $NaCd_2$. It is evident from these curves that the summits of many of the branches lie below other branches, and therefore correspond to unstable states. The position of the summit and the formula of the compound must in such cases be a matter of speculation until experiments of another kind have been made.[1]

M. Kurnakov has also studied the crystalline matter which separates at the freezing-points, and has noted great variations in this as one goes from one branch to another. He separated by filtration the hexagonal plates which crystallise at points along the branch BC, and analysed them.

FIG. 5.



Atomic percentage.

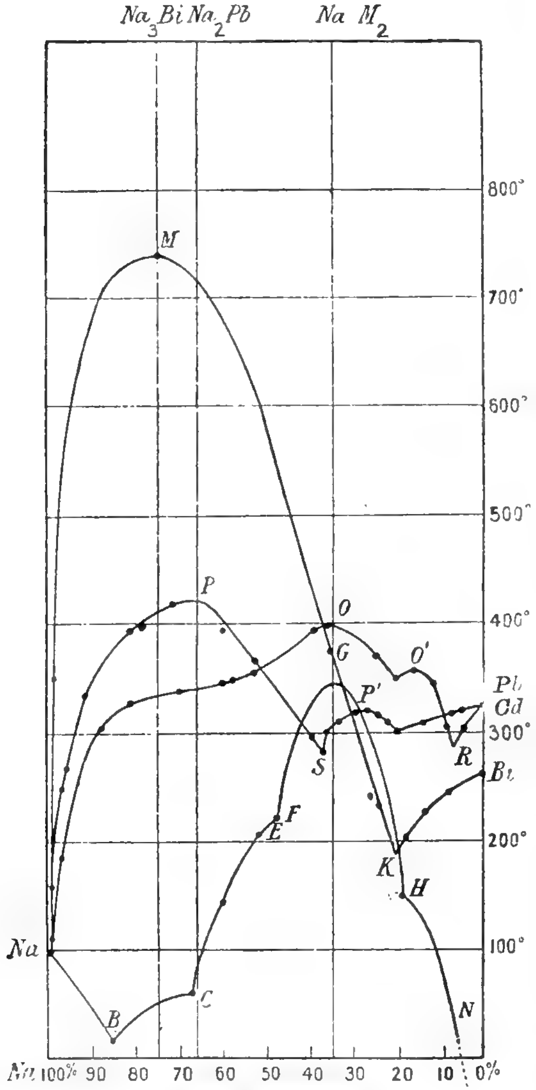
He found, however, that the composition of the crystals varied from point to point along the branch. He attributes this to the presence of mother liquor attached to the crystals, and he thinks that the crystals, if free from mother liquor, would have had the formula Na_2Hg. This is a very reasonable supposition, but it may be that he was examining mixed crystals. The formation of mixed crystals of two bodies which crystallise isomorphously is certainly common in alloys, and may be the cause of singularities in the freezing-point curve. Indeed, it is doubtful if we

[1] The amalgams of sodium and potassium have been examined by various other methods; for example, by the determination of their specific volume—a method recently employed by E. Maey (*Zeits. Phys. Chemie*, xxix. p. 119). He finds a number of angles in his plotted curve which he attributes to the existence of compounds.

shall arrive at certainty in the interpretation of such curves until this question of mixed crystallisation has been thoroughly studied. M. Le Chatelier some years ago pointed out the importance of this question and studied it.

The curve for mixtures of silver and gold has been quoted as a type for bodies which form mixed crystals in all proportions. It is a continuous curve joining the points of fusion of the two components, and differs from such a curve as that of fig. 1 by consisting of one branch only. Mixed crystallisation of two bodies, one or both of which were compound, might be indicated by a continuous curve joining the freezing-points of the two proximate constituents of the crystals. There are probably several such cases in the curves given by M. Gautier. Charpy and Stead have independently studied with the microscope a peculiar crystal structure which they conjecture to be due to mixed crystallisation. But no case of isomorphism in alloys has been worked out in a manner that is conclusive. Until lately a satisfactory theory of the subject was lacking, but Professor Roozeboom (16), to whom physical chemists owe so much, has lately investigated it, and MM. Van Eyk, Reinders, and Hissink have verified his views in the case of certain mixtures of two salts. It seems very desirable that students of alloys should begin to work in the light of this theory. An attempt will therefore be made here to state Roozeboom's view in the simplest case he gives.

FIG. 6.



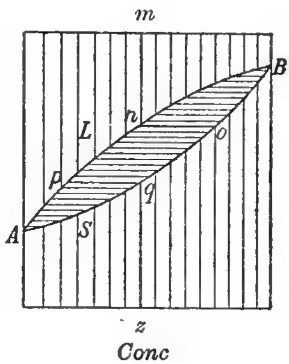
Atomic percentage.

For this purpose we must look again at fig. 1, the curve for a pair of metals which neither combine chemically nor form mixed crystals. Here the region above the curve corresponds to liquid states, the line of the curve to equilibrium between a liquid and crystals of A for the left branch and B on the right branch; the region below the curve, but above the angle, to mixtures of solid A or B with varying liquids; and, finally, all the

region below the eutectic angle to solid conglomerates of separate crystals of A and B. The range of temperature between the first appearance of crystals in a liquid alloy and its complete solidification is measured by the vertical line drawn from a point on the curve to the level of the eutectic point.

Let us now suppose that the two metals, which we will still call A and B, can form mixed crystals in all proportions. According to Roozeboom there will be no angle of intersection of the two curves, but the freezing-points of A and B will be joined by a continuous curve, the points on which correspond to exactly saturated liquids. He calls this the 'L' or 'liquid' curve. But also starting from the freezing-points of A and B, and lying under the 'L' curve, a continuous curve can be drawn giving the composition of the mixed crystals that form at each temperature. He calls this the 'S' or 'solid' curve. The case is represented in fig. 7, which, together with figs. 8 and 9, is taken from his paper. To find what happens at a particular temperature, draw a horizontal line cutting the 'L' curve in n and the S curve in o. These two points of intersection give the composition of the two phases that can exist together at the temperature of the horizontal line. In fig. 7 n gives the composition of the liquid that when it begins to freeze deposits mixed crystals of the percentage o.

FIG. 7.



The complete process of freezing can now be stated. Draw through n a vertical line $m\,n\,q\,z$ cutting the L curve in n and the S curve in q. Then n and all points above it correspond to uniform liquid, q and all points below it to a uniform mass of mixed crystals (not, as in fig. 1, to a conglomerate of crystals of A and B). The temperature range during freezing is $n\,q$, and during the process, if perfect equilibrium is ensured, the solids formed undergo continuous transformation from the composition o to that of q, while the liquid remaining at any moment changes from n to p, where p is the intersection of L by a horizontal through q. Thus all the areas shaded vertically represent homogeneous states—above L of a liquid, below S of homogeneous crystals. The part between L and S, shaded horizontally, represents states in which a solid is mixed with a liquid.

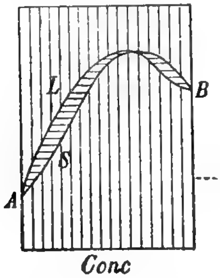
The L and S curves may have a maximum or a minimum, in both of which cases they touch each other at the maximum or minimum point, as in figs. 8 and 9.

The liquid whose composition is that of the maximum or minimum will solidify completely at one temperature. Hence in the case of the maximum one might mistake the solid for a definite chemical compound, and in the case of a minimum for a eutectic mixture. One must remember that the diagram need not stand for the whole freezing-point curve of two elements, but for the horizontal space between the two points corresponding to compounds, and we can treat the compounds themselves as the components of the mixed crystals. Our copper-tin curve probably shows such a case in the region between Cu_5Sn and Cu_4Sn.

These considerations point to a great danger in the interpretations of the minor details in complicated freezing-point curves such as those of Kurnakov, Gautier, and our AuAl curve. Given perfect equilibrium transformations during cooling, it should be fairly easy by appropriate

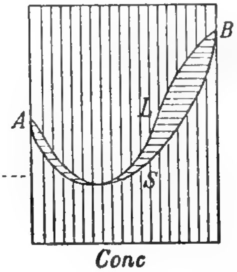
experiments to discriminate between a summit due to the existence of a chemical compound and one due to the form of a mixed crystal curve. In

FIG. 8.



Roozeboom

FIG. 9.



such cases as Kurnakov's $NaHg_2$ and KHg_2, our Au_2Al, and Roberts-Austen's $AuAl_2$, where the formula of the summit is an exact and simple one, there can be little doubt. A microscopic examination of the summit alloy might not help, but that of alloys at some distance on either side of the summit ought to settle the matter. If they are homogeneous, give a uniform ignition colour, and etch all over at the same rates, the summit must be due to mixed crystals ; while if the alloys show primary crystallisation embedded in a mother substance, the primary crystals continually decreasing in amount as we go down the curve, the summit is probably a compound. This is the structure we found near the two summits of the AuAl curve.

But Roozeboom points out as the best method of attacking such questions the two following series of experiments : (1) Determine not only the freezing-point of each alloy, but also the temperature at which it sets to a solid mass. From these data, both of the curves L and S could be plotted. The setting-point would probably not be very sharply marked, but a recording pyrometer would indicate its whereabouts by a greater rapidity in cooling after the point was passed. Cooling-curves such as those of Sir W. Roberts-Austen might be made to give the information needed for plotting the S curve. We, in a very imperfect way, sought for the setting-points in determining our AuAl curves, but found instead the usual horizontal lines of second freezing-points. The existence of these renders mixed crystals improbable.

The other line of research, adopted by Reinders and Van Eyk and Hissink, is to extract the first crystals that form and analyse them, as well as the mother liquor from which they were taken. If this were done for alloys on either side of a summit due to a compound, we should find the crystals having all the same composition—namely, that of the compound ; while if the summit were due to the existence of mixed crystals, the solids extracted from alloys of various compositions would differ widely. There can be no doubt that this process, troublesome though it would be, is the proper way to attack the interpretation of a complicated freezing-point curve.

A few cases out of many may be mentioned where mixed crystals are probable in alloys : between Cu_5Sn and Cu_4Sn, in lead-thallium alloys, in bismuth-antimony, in gold-silver, in alloys containing zinc or cadmium with either silver, copper, or gold.

A careful study of some of these cases is probably the most pressing

need at present in intermetallic chemistry. The difficulty of this subject, whether we use the freezing-point curve or the microscope, is increased by the uncertainty as to the maintenance of perfect equilibrium at each stage of the cooling.

Microscopic Examination.

Osmond, Charpy, and Stead have shown us how much light the microscope throws on our subject.

The microscopic examination of the pattern shown by the polished surface of an alloy that has, if necessary, been etched or heated to produce oxidation colours seems to bring us nearer to the phenomena than other methods of experiment. It is often quite easy to determine which crystals formed first in the freezing (the primary crystallisation), but there are certain types of pattern that are very puzzling. Among the points calling for an answer are the following :

1. Does the existence of coated crystals, such as one finds in gunmetal and also bronzes containing more tin than Cu_3Sn, indicate the existence of a second compound ? The answer is, Yes, in some cases—for example, in the AuAl curve and, as Mr. Stead thinks, in the bronzes rich in tin, where the Cu_3Sn crystals are coated with CuSn. M. Le Chatelier has lately pointed out that in all such cases the solid alloy is not in equilibrium and that the effects of annealing will generally be great.

2. Can the existence of series of mixed crystals be detected by the microscope ?

M. Charpy and Mr. Stead both describe a similar structure, and are disposed to attribute it to this cause.

3. How far will the microscope supplement the very meagre indications that the curve sometimes gives of a compound ?

As an answer one can take the portion of our copper-tin freezing-point curve (fig. 10) between Cu_4Sn and Cu_3Sn. The curve is almost straight, the swelling (one cannot call it a summit) corresponding to Cu_3Sn being very slight. But the microscope shows Cu_4Sn as a homogeneous body, while alloys with a little more tin show new crystals embedded in this and sharply separated. These new crystals increase as we add more tin, until at Cu_3Sn they fill the whole alloy ; thus the microscope is here much more decisive in its indications than the curve.

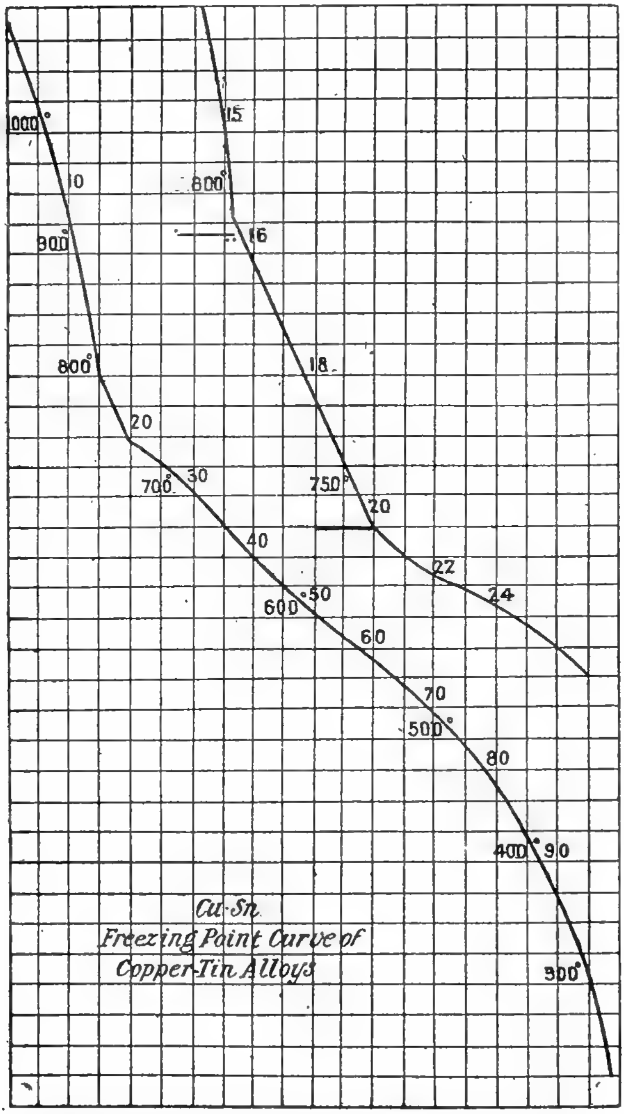
Röntgen-ray Photography.

Skiagraphs of thin sections of alloy which contain one transparent metal, such as sodium or aluminium, and one metal more opaque, sometimes give fine views of the crystals in the alloy. This method has the advantage of showing the structure of the alloy as it is before any etching or other reagent has modified it. The two photographs shown were taken some years ago by Mr. Heycock and myself. The first is aluminium alloyed with ten per cent. of antimony. One sees that a heavy compound has crystallised out first. This is in harmony with M. Gautier's curve which presents no branch along which primary crystals of aluminium could form. If a series of such photographs had been taken with increasing percentages of Sb, we might have been able to locate the percentage at which the compound was pure.

The other photograph is one of aluminium containing ten per cent. of nickel. One sees that an opaque body has again crystallised first The varying thickness of some of the crystals gives them an effect of solidity which is absent from a surface photograph.

Unfortunately the alloys have to be very slowly cooled in order to obtain large crystals. Magnification during the process of taking the skiagraph is clearly impossible, and as the figure on the plate is not a real optical image, but a shadow from a radiant point of finite size, it is not sharp enough to bear great magnification afterwards. The method, however, is capable of doing more than it has done yet. It was first successfully carried out by Mr. Heycock and shown by him in a lecture at the Royal Institution.

FIG. 10.



The numbers below the curve give the Centigrade temperature; the numbers above the curve give the atomic percentage of tin in the alloy.

Electrical Methods.

Herschkowitz ([17]), following Laurie ([18]), has compared the electrical potential of a number of binary alloys with that of the more positive metal contained in each alloy, the electrolyte being always a salt of the more positive metal dissolved in water.

From theoretical considerations he concludes that when the solid alloys contain only separate crystals of the two metals A and B, the potential of all the alloys will be that of the more positive metal A (a point practically proved by Laurie's experiments), so that if we plot the composition of the alloys horizontally, and their potential referred to that of A vertically, we shall get a horizontal straight line; this is realised in the pair Cd–Bi. If, however, the two metals mutually dissolve each

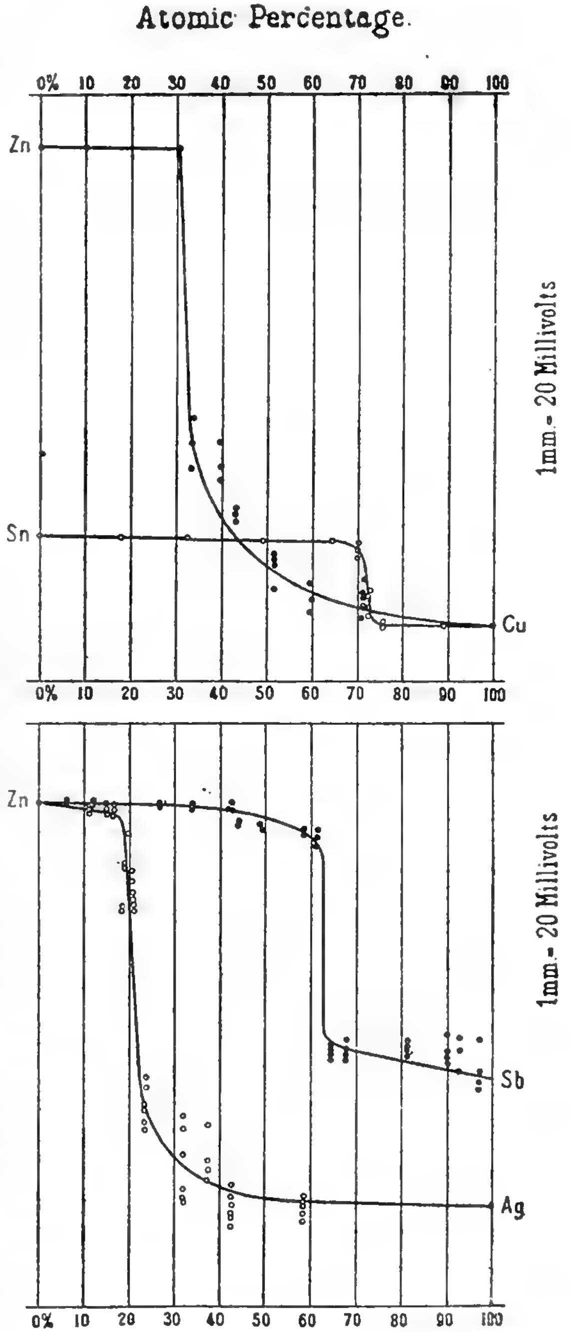
other, but to a limited extent, the curve will show a depression as we leave pure A, a flat for alloys containing two conjugate solid phases each a saturated solution of one metal in the other, and a further depression as we approach pure B. If, however, compounds of A and B exist, that one nearest in composition to A will be indicated by a marked fall in the potential as we reach its formula in going from A to B along the curve. He gives experimental curves showing that this is the case with the following pairs :—

ZnCu at Zn_2Cu.
ZnAg at Zn_4Ag.
ZnSb at $ZnSb_2$.
SnCu at $SnCu_3$.
SnAg at $SnAg_4$.

The curves, four of which are reproduced in this report (fig. 11), show that the phenomena are well marked. The numbers in the figures running from left to right are atomic percentages of the metal whose symbol is on the right of the figure.

If we compare Herschkowitz's SnCu curve with our freezing-point curve for the same metallic pair in which the indication of the existence of $SnCu_3$ is of the slightest kind, we see how very useful the method may be in detecting compounds. It appears, however, that only one compound of each metal pair is likely to be indicated by the method. It is probable that the method, if it can be carried out accurately, will give us valuable indications as to the solubility of one metal in the other in the solid state—a point on which both the microscope and the freezing-point curve are ambiguous. Although Laurie was the originator of this method, the work of Herschkowitz has been quoted, as it is more recent and founded on a clearer theory.

FIG. 11.



Heat of Formation.

It is probable that if two metals form compounds whose heat of formation is considerable, whether positive or negative, and if we could determine the heat of formation of a series of binary alloys of these two metals, we should find a maximum or a minimum heat evolution at formulæ corresponding to those of the compounds. Herschkowitz has attempted to find these heats of formation by dissolving first the metals, then the alloy, in a solution of bromine and KBr in water, and taking the difference as the heat of formation of the alloy. But his results, though not unpromising, do not yet throw much light on our subject. One objection to his method lies in the necessity of crushing his metals and alloys to ensure rapid solution in the calorimeter. Now, as Mr. Rosenhain has pointed out to me, it is certain that the crushed alloy, each fragment of which has been strained, possesses more energy than it did before crushing, and this may be quite important as compared with the small heats of formation observed.

Galt [19] and other workers have followed similar methods, but the solvent (nitric acid) used by him does not seem a safe one, as the gaseous products of solution may be so varied that one can feel no certainty that the final state was the same in the solution of the metals and of the alloy. In Tayler's [20] method of dissolving the metals and the alloy in mercury there is not this danger, but the applicability of the method is more limited.

Electric Conductivity of Alloys.

Since Matthiessen and Wiedemann studied the remarkable changes in conductivity produced by alloying two metals, this subject has been one of great interest. But it is doubtful if research in this direction will help us much in detecting the existence of compounds. For the increase in resistance due to alloying two metals, while partly due to the Peltier effects at the innumerable surfaces of contact of the crystals forming the alloy, is also due to the mechanical discontinuities and gaps which exist in alloys. It would be very difficult to distinguish quantitatively between the effects due to the two causes. The impossibility of drawing many alloys into wire, and the changes caused by drawing those which are ductile, also limit and complicate this method of research.

PART II.

Table of Intermetallic Compounds.

Column 2 contains the presumed formula of the compound. Column 3 indicates the kind of evidence on which the formula is based. In column 3 the letters F.P.C. stand for freezing-point curve; I. for the fact that the body has been isolated and analysed; M. for microscopic proof; E.M.F. for determinations of electromotive force, such as those of Laurie.

Column 4 gives the name of the experimenter, and a number referring to the table of references, which is placed at the end of the report. The more uncertain formulæ are placed in brackets. Each alloy occurs twice in the table.

Intermetallic Compounds.

Na	$NaHg_2$	F.P.C.	Kurnakov (15)
	$NaCd_2$	"	"
	Na_2Pb	"	"
	"	I.	Joannis (4)
	Na_3Bi	F.P.C.	Kurnakov (15)
	"	"	Joannis (4), Lebeau (3)
	Na_3Sb	"	" "
	Na_3As	"	Lebeau (3)
	Na_4Sn	"	"
K	KHg_2	F.P.C.	Kurnakov (15)
	KPb	I.	Joannis (4)
Ag	Ag_3Sb	F.P.C.	Heycock and Neville (21)
	"	A mineral	
	"	M.	Charpy (9)
	Ag_2Sn	"	"
	Ag_4Sn	E.M.F.	Herschkowitz (17)
	Ag_2Al	F.P.C.	Gautier (10)
	(Ag_4Cd)	F.P.C. of ternary alloy	Heycock and Neville (1)
	(Ag_2Cd)		
Zn	Zn_4Ag	E.M.F.	Herschkowitz (17)
	Zn_2Cu	"	Laurie (18), Herschkowitz (17)
	"	I.	Le Chatelier (6)
	"	M.	Charpy (9)
	Zn_2Sb	E.M.F.	Herschkowitz (17)
Cd	AuCd	I.	Heycock and Neville (1)
	"	F.P.C. ternary	
	Cd_2Na	F.P.C.	Kurnakov (15)
	$(CdAg_2)$	F.P.C. of ternary alloys	Heycock and Neville (1)
	$(CdAg_4)$		
Hg	Hg_2Na	F.P.C.	Kurnakov (15)
	Hg_2K	"	"
Cu	Cu_2Sb	F.P.C.	Le Chatelier (6)
	"	M.	Charpy (9)
	Cu_3Sn	I.	Le Chatelier (6)
	"	E.M.F.	Laurie (18), Herschkowitz (17)
	$CuAl_2$	F.P.C.	Le Chatelier (14)
	Cu_3Al	"	"
Al	Al_2Au	F.P.C. & M.	Roberts-Austen (24)
	(AlAu)	" "	Heycock and Neville (22)
	$AlAu_2$	" "	" "
	(Al_2Au_5)	" "	" "
	$(AlAu_4)$	" "	" "
	Al_2Cu	"	Le Chatelier (14)
	$AlCu_3$	"	"
	$AlAg_2$	"	Gautier (10)
	AlSb	"	"
	"	I.	Wright
As	$AsNa_3$	I.	Lebeau (3)
	As_2Sn_3	I.	Stead (7)
Sb	$SbNa_3$	I.	Joannis (4), Lebeau (3)
	$SbAg_3$	F.P.C.	Heycock and Neville (21)
	$SbCu_2$	"	Le Chatelier (14)
	"	M.	Charpy (9)
	SbSn	I. and M.	Stead (7)
	Sb_2Zn	E.M.F.	Herschkowitz (17)
	SbAl	F.P.C.	Gautier (10)
Bi	$BiNa_3$	"	Kurnakov (15)
	"	I.	Joannis (4)
Au	(Au_4Al)	F.P.C. & M.	Heycock and Neville (22)
	(Au_5Al_2)	" "	" "
	Au_2Al	" "	" "
	(AuAl)	" "	" "

Intermetallic Compounds—continued.

Au	$AuAl_2$	F.P.C. & M.	Roberts-Austen [24]
	Au_4Pb	M. and I.	Stead (unpublished)
	Au_5Pb_2	M.	,,
Sn	$SnNa_4$	I.	Lebeau [3]
	$SnCu_3$	I.	Le Chatelier [6]
	,,	E.M.F.	Laurie [18], Herschkowitz [17]
	,,	M.	Stead [7], Charpy [9]
	,,	I. by Sn in $CuCl_2$	Mylius and Fromm [23]
	($SnCu$)	M.	Stead [7]
	($SnCu_4$)	M. & F.P.C.	Heycock and Neville [21]
	($SnAg_2$)	M.	Charpy [9]
	$SnAg_4$	E.M.F.	Herschkowitz [17]
	$SnSb$	I. and M.	Stead [7]
	Sn_2Ni_3	F.P.C.	Le Chatelier [10]
	Sn_3As_2	I.	Stead [7]
	Sn_3Ru	,,	Debray [5]
	Sn_3Rh	,,	,,
	Sn_3Ir	,,	,,
	Sn_4Pt	,,	,,
Pb	$PbNa_2$	F.P.C.	Kurnakov [15]
	PbK	I.	Joannis [4]
	$PbAu_4$	M. and I.	Stead [7]
	Pb_2Au_5	,,	,,
Rh	$RhSn_3$	I.	Debray [5]
Ru	$RuSn_3$	,,	,,
Ir	$IrSn_3$	,,	,,
Pt	$PtSn_4$	,,	,,

It would be very easy to amplify this list; for example, various other arsenides and antimonides have had formulæ assigned to them, and some alloys of aluminium and tin with the rarer metals appear to have been isolated as crystals. Further research will no doubt enormously expand it, though it may also cause the rejection of a few that have been included.

But as the list now stands it offers matter for the consideration of the student of valency. One sees that the compounds of the metalloids with the metals present formulæ that we should expect from the known valencies of the elements, but such bodies as $NaHg_2$, $SnCu_3$, $AlAg_2$ are more remarkable. The first of these is evidently a well-marked type, which already occurs several times.

If I rightly understand Professor Kurnakov, he thinks that Mendeléef's law of the total valency of an element for oxygen and hydrogen being 8 will find application in the formulæ of alloys, the hydrogen being replaced by other metals. In this case, the alkali metals which are monovalent to oxygen should be polyvalent in alloys; his curves certainly support this view. The freezing-point curves show that the most marked summits—that is, the most stable compounds—occur when a strongly positive metal, such as sodium or aluminium, is alloyed with a metal, such as antimony, lead, or gold, which is far removed from it in the electro-chemical series.

The Molecular Weights of Metals.

With the exception of the limited number of vapour-density determinations which show that mercury, cadmium, and zinc, and perhaps also sodium and potassium, have monatomic molecules when gaseous, the only evidence as to the molecular weights of metals lies in experiments based on Raoult's methods.

Professor Ramsay and M. Tammann in 1890 showed that small quantities of various metals dissolved in mercury gave, for the most part, depressions of the vapour-pressure and of the freezing-point, which indicated that the dissolved molecule contained one atom of the added metal. At the same time, Mr. Heycock and I found that this was in general true when metals were dissolved in tin. At later dates we extended the generalisation to solutions of metals in the solvents bismuth, cadmium, lead, and zinc, and tables summarising our results are reproduced in the present report. If we could be certain that the dissolved metal did not form a chemical compound with the solvent, these results would afford very strong grounds for holding that the molecules of the dissolved metals were in most cases monatomic. But we know now that chemical combination is not uncommon, and it is evident that in dilute solution the dissolved metal A will tend to form compounds of the type $A\,B_m$, where B is the solvent. Hence the problem of the chemical compounds formed by metals with the solvent metal must be solved before we can safely dogmatise concerning the molecular weight of the metals when in solution. To take a special case, one atom of copper dissolved in tin produces the molecular depression of the freezing-point, but from Mr. Stead's work we have good reason to attribute this to the presence of a molecule CuSn.

On the other hand, the abnormal depressions obtained by us in certain cases point to the probability of the compounds Bi_nAs_3, Bi_nCu_2, Cd_nHg_2, Cd_nZn_2, Cd_nPd_2, Cd_nK_2, Cd_nAu_3, Cd_nAs_3, $Pb_n(Cd, Hg, Bi)_2$, Pb_nSn_4, Pb_nNa_6, most of which have not at present been studied. It is obvious that n may be zero in any of these.

The question of the depression of the freezing-point in dilute solutions, is, however, complicated by the probable appreciable solubility of the dissolved metal in the solid crystals of solvent, and by all the thermal difficulties that Nernst and Abegg have discussed.

The fascinating question as to the condition of association or dissociation of the molecules of the compounds when melted or in solution also comes in when we attempt to interpret our tables, or, indeed, when we examine any freezing-point curve. But it is possible to study intermetallic compounds without touching this question, and in the present report I have thought it best to do so.

The vast subject of ternary and more complex mixtures has also been avoided as too complex for the present purpose, although Behrens, Stead, and especially Charpy, have made most interesting studies of such mixtures.

I have to thank Mr. Heycock for continued assistance in drawing up this report. I have also to thank Mr. Stead and Professor H. Le Chatelier for valuable information and valuable references.

Depression of the Freezing-point of the Metals Tin, Zinc, Bismuth, Cadmium, and Lead, caused by the Solution of Small Quantities of other Metals.

The theoretical molecular depressions are calculated from the latent heat of fusion by means of the formula

$$\delta\theta = 0{\cdot}02\frac{\theta^2}{\lambda}$$

where θ is the freezing-point of the pure metal, $\delta\theta$ the depression, and λ the latent heat of fusion.

TABLE I.—*Tin as Solvent.*
Atomic Falls for a Concentration of under one Atom.

Group	Metal	Atomic fall	Experiments
I.	Nickel	2·94	3 experiments.
	Silver	2·93	2 „
	Gold	2·93	6 „
	Copper	2·91	2 „
	Thallium	2·86	4 „
	Sodium	2·84	2 expts. concn. 1—3 atoms.
	Palladium	2·78	4 experiments.
	Magnesium	2·76	1 „
	Lead	2·76	8 „
	Zinc	2·64	4 „
II.	Cadmium	2·43	3 experiments.
	Mercury	2·39	4 „
	Bismuth	2·40	6 „
	Calcium	2·40	2 „
III.	Indium	1·86	5 experiments.
	Aluminium	1·25	1 „

Theoretical Molecular Depression = 3° C.

TABLE II.—*Zinc as Solvent.*

Metal.	Extreme atomic percentage.	Mean atomic percentage.	Mean depression.	Mean atomic depression.
Bismuth	0·386	0·2075	1·052°	5·07
Antimony	0·799	0·4377	2·247	5·13
„ from curve	0·500	0·500	2·60	(5·20)
Lead	0·200	0·150	0·78	5·20
Thallium	0·393	0·2595	1·285	4·95
Tin	1·187	0·655	3·497	5·34
Magnesium	0·975	0 655	3·572	5·45
Cadmium	1·464	0·732	3·377	4·61
Aluminium	0·99	0·99	4·10	(4·14)

Theoretical Molecular Depression = 5·13° C.

TABLE III.—*Bismuth as Solvent.*

—	No. of experiments.	No. of atoms per 100 atoms Bi.	Mean atomic depression.
Lead	20	1·1—1·75	2·1
Thallium	2	0·3—0·9	2·07 M.
Mercury	4	0·3—4·3	2·04
Tin	4	0·16—2·2	2·03. Steady.
Palladium	4	0·9—2·2	2·03
Platinum	6	0·2—1·2	2·02. Steady.
Cadmium	4	1·0—4·0	2·01
Gold	4	0 4—1·8	1 97
Sodium	3	0·8—4·0	1·94. Steady.
Silver	3	0·7—2·5	1·91
Zinc	4	1·3—4·8	1·6
Copper	5	0·23—0·6	1·23
Arsenic	5	0·25—2·3	0·68. Very steady.
It is noticeable that arsenic both in bismuth and cadmium gives $\frac{1}{3}$ fall.			
Antimony	3	0·23—1·0	2·79. Rise.

Theoretical molecular depression = 2·08° C.

TABLE IV.—*Cadmium as Solvent.*

—	No. of experiments.	No. of atoms per 100 atoms Cd.	Mean atomic depression.
Antimony	2	0·3—0·5	4·71 M.
Platinum	2	0·08—0·13	4·55
Bismuth	4	0·05—0·5	4·58
	3	2·2—3·6	4·09
Tin	2	0·66—2·6	4·48
Sodium	3	0·6—1·3	4·44
Lead	2	0·84—1·4	4·4
Thallium	3	0·24—1·28	4·34 M.
Copper	8	0·2—2·0	3·5. No falling off.
Mercury	3	0·23—0·68	2·77
Zinc	3	0·06—1·6	2·72. No falling off.
Palladium	3	0·13—0 26	2·35
Potassium	2	0·5—0·6	2·26 M.
Gold	3	0·14—0·7	1·48
Arsenic	1	0·2	1·6
Silver	1	0·05	9·33. Rise.

Theoretical molecular depression = 4·5° C.

TABLE V.—*Lead as Solvent.*

—	No. of experiments.	No. of atoms per 100 atoms of Pb.	Mean atomic depression.	
Gold	4	0·33—2·7	6·45.	Steady.
Palladium	3	0·32—1·8	6·45	
Silver	6	0·2—1·4	6·45	
Platinum	4	0·15—0·6	6·42	
Copper	3	0·1—0·195	6·15	
Arsenic	4	0·38—4·9	5·33	
Magnesium	2	1·5	4·56	
Zinc	3	0·2—1·2	4·43	
Antimony	4	0·6—4·7	3·9.	Steady.
Cadmium	2	0·6—6·1	3·62	Steady.
Mercury	3	0·73—6·7	3·31	$\frac{1}{2}$ Hg_2.
Bismuth	6	0·23—4·6	3·02	Steady.
Tin	3	0·4—1·8	1·8	$\frac{1}{4}$ Sn_4.
	2	6·0—9·0	1·6	
Sodium	2	—	1·06 ?	

Theoretical molecular depression = 6·5° C.

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Bibliography of Spectroscopy.—Report of the Committee, consisting of Professor H. McLeod, Professor Sir W. C. Roberts-Austen, Mr. H. G. Madan, *and* Mr. D. H. Nagel.

The work of collecting, verifying, and systematically arranging the titles of papers bearing on spectroscopy has been steadily carried on during the past year; and the Committee ask to be reappointed for one more year, with the intention of presenting to the Association at its next meeting the final instalment of the 'Catalogue of Spectroscopic Literature,' commenced in 1870. It is proposed to end the catalogue with the present century, since the very satisfactory character of the proceedings at the last conference of the delegates appointed to arrange the compilation of an International Catalogue of Scientific Papers seems to warrant the conclusion that, as from January 1, 1901, the services of the Committee will be no longer needed.

Absorption Spectra and Chemical Constitution of Organic Substances.—Interim Report of the Committee, consisting of Professor W. NOEL HARTLEY (*Chairman and Secretary*), Professor F. R. JAPP, *and* Professor J. J. DOBBIE, *appointed to investigate the Relation between the Absorption Spectra and Chemical Constitution of Organic Substances.*

FOUR informal meetings have been held during the year, and, as much work is still in progress, it has been considered desirable that an interim report of that which has been completed should be presented. This consists of five communications published by the Chemical Society in their 'Transactions' since March last. Two of these deal with the subject of tautomerism and one with stereo-isomerism. The fourth is a study of ammonia and its derivatives, of hydroxylamine and oximes; and the fifth an examination of some closed-chain compounds one of which contains two nitrogen atoms. Details of the measurements of the spectra are omitted from this report for the sake of brevity. In connection with the nitrogen compounds a brief abstract of a previous publication has been included. It is of interest because it leads towards the conclusion that there are two distinct classes of albuminoids, some of which have long been known to act as enzymes or soluble ferments towards the carbohydrates.

Spectrographic Studies in Tautomerism.

I. *Absorption Curves of the Ethyl Esters of Dibenzoylsuccinic Acid.*[1]

According to theory, thirteen isomerides of diethyl dibenzoylsuccinate have a possible existence, but only three have so far been prepared and studied. On chemical grounds Knorr[2] regards one of the three as an enolic, and the other two as ketonic esters. He assigns to the enolic or α-ester the constitutional formula

$$\begin{array}{r@{}c@{}l} \mathrm{CPh(OH){:}} & \mathrm{C} & \mathrm{{\cdot}CO_2Et} \\ & | & \\ \mathrm{CPh(OH){:}} & \mathrm{C} & \mathrm{{\cdot}CO_2Et} \end{array}$$

without deciding which of the three possible stereo-isomeric modifications of this formula represents the substance examined by him. The two ketonic esters are structurally identical but configuratively different. To one of them, which he designates the para- or β-ester, Knorr assigns the formula (a), and to the other, which he designates the meso-, anti or γ-ester, the formula (b).

$$(a)\quad \begin{array}{r@{}c@{}l} & \mathrm{H} & \\ & | & \\ \mathrm{CO_2Et{\cdot}} & \mathrm{C} & \mathrm{{\cdot}COPh} \\ & | & \\ \mathrm{COPh{\cdot}} & \mathrm{C} & \mathrm{{\cdot}CO_2Et} \\ & | & \\ & \mathrm{H} & \end{array} \qquad\qquad (b)\quad \begin{array}{r@{}c@{}l} & \mathrm{H} & \\ & | & \\ \mathrm{COPh{\cdot}} & \mathrm{C} & \mathrm{{\cdot}CO_2Et} \\ & | & \\ \mathrm{COPh{\cdot}} & \mathrm{C} & \mathrm{{\cdot}CO_2Et} \\ & | & \\ & \mathrm{H} & \end{array}$$

[1] Hartley and Dobbie, *Trans. Chem. Soc.*, vol. lxxvii.
[2] *Annalen*, 1896, **293**, 70.

A mixture of the β- and γ-esters is readily obtained by adding an ethereal solution of iodine to the sodium derivative of ethyl benzoylacetate, obtained by the action of metallic sodium on an ethereal solution of the ester. The two ketonic esters are readily separated from one another by fractional crystallisation. When either of them is treated with sodium methoxide, a yellow crystalline meal, consisting of the sodium derivative of the α-ester, is obtained. The aqueous solution of this substance, when treated with excess of dilute sulphuric acid at the freezing temperature, yields the α-ester, which separates as a thick oil possessing the colour of chlorine gas. The β-ester, which was first described by von Baeyer and Perkin,[1] melts at 128–130°, the γ-ester at 75°, and the former is less soluble than the latter in most solvents. Both esters are optically inactive, the β-ester by external, the γ-ester by internal compensation. The ketonic esters are neutral to litmus, and practically insoluble in cold dilute alkalis. In their chemical properties they are exactly alike.

The α-ester differs, both in physical and chemical properties, from the ketonic esters. It is an oily liquid, has a strongly acid reaction, and dissolves in cold dilute alkalis. It gives a characteristic dirty brown coloration with ferric chloride, which is not shown by the ketonic esters, and moreover is unstable, gradually passing into a mixture of the β- and γ-esters at the ordinary temperature, the change taking place quickly at 130°.

f the view put forward by Knorr as to the relation of the three esters to one another is correct, the β- and γ-esters should give very similar, if not identical, absorption curves, since stereo-isomerides which differ only in the configuration of their asymmetric carbon atoms so far as they have been investigated in essential oils and their hydrocarbons, are not found to differ either in the amount or the character of their absorption. The α-ester, on the other hand, having a different constitution, should exhibit a distinct series of absorption spectra.

We have photographed and measured the spectra of alcoholic solutions of the three substances, and the results obtained entirely bear out the conclusions arrived at by Knorr on purely chemical grounds. The spectra of the ketonic esters are identical. The amount of absorption is considerable, all rays beyond $^1/\lambda$ 2795 being cut off by a layer 25 mm. thick of a solution containing 1 milligram-mol. in 100 c.c. of alcohol. There is also a well-marked band of selective absorption reaching from $^1/\lambda$ 3824 to $^1/\lambda$ 4306 in a layer 3 mm. thick of a solution containing 1 milligram-mol. of the ester in 2500 c.c. of alcohol. This band is very persistent, and is still distinctly marked in a layer 4 mm. thick of a solution containing only 1 milligram-mol. in 12,500 c.c. of alcohol.

The spectrum of the α- or enolic form is quite different from that of the ketonic esters. The general absorption is greater, a layer 25 mm. thick of a solution containing 1 milligram-mol. in 100 c.c. of alcohol cutting off all rays beyond $^1/\lambda$ 2171. The absorption band of the ketonic esters is altogether absent, whilst a well-marked band makes its appearance in a layer 5 mm. thick of a solution containing 1 milligram-mol. in 500 c.c. of alcohol between $^1/\lambda$ 2546 and $^1/\lambda$ 3148. This band quickly dies out, no trace of it being visible in a layer 4 mm. thick of a solution containing 1 milligram-mol. in 500 c.c. of alcohol.

[1] *Ber.* 1884, **17**, 60.

The absorption curves for the ketonic and enolic forms are shown in the diagram on p. 156.

When the solution of the α-ester was allowed to stand, and photographs were taken after successive intervals of time, the transition from the enolic to the ketonic form could be clearly traced. *After an interval of only three hours, the absorption band of the enolic ester had almost entirely disappeared, whilst the amount of general absorption had also appreciably diminished.* Solutions containing 1 milligram-mol. in 100 and 500 c.c. respectively showed after forty-eight hours a great diminution in the amount of the general absorption, whilst after three weeks the curve coincided almost exactly with that of the β- and γ-esters, as shown on p. 155.

The result of this investigation exemplifies the value of the spectrographic method, and shows how it might be applied with advantage to the investigation of similar cases of isomerism either to guide the chemical investigation or to confirm the conclusions drawn from it, especially when any doubt exists as to whether the isomerism is due to a difference in constitution or merely to a difference in the arrangement of the atoms in space. The amount of substance required for the experiments is small, and can generally be recovered again from the solution.

The esters were prepared by the method described by Knorr.[1] The preparation of the β- and γ-esters offers no difficulty: the α-ester is only obtained when strict attention is paid to all the details given by Knorr. Two distinct preparations of each of the ketonic esters and three preparations of the α-ester were made. Each preparation was photographed several times without any difference being observed in the photographs of the same substance. In the case of the α-ester the photographs were taken immediately after the completion of the preparation, as the change to the ketonic form sets in almost at once.

II. *A Study of the Absorption Spectra of* o-*Oxycarbanil and its Alkyl Derivatives.*[2]

The substance *o*-oxycarbanil, $C_7H_5O_2N$, and its alkyl derivatives form a group of compounds which stand in the same relation to one another as isatin, carbostyril, and their respective alkyl derivatives.

o-Oxycarbanil can be prepared by the fusion of *o*-aminophenol hydrochloride with urea, or from its lactim ether by the action of concentrated hydrochloric acid.[3] It can also be obtained by the distillation of *o*-aminophenyl ethyl carbonate.[4] Two ethyl derivatives of *o*-oxycarbanil are known. One of these is prepared by boiling *o*-oxycarbanil for some time under a reflux condenser with equivalent quantities of ethyl iodide and alcoholic potash, the other by the interaction of *o*-aminophenol and ethyl iminocarbonate. The ether obtained by the first method is considered to be a lactam, that is, to have the ethyl group directly attached to the nitrogen atom, because on heating for some time with hydrochloric acid it takes up water and decomposes into carbon dioxide and the hydro-

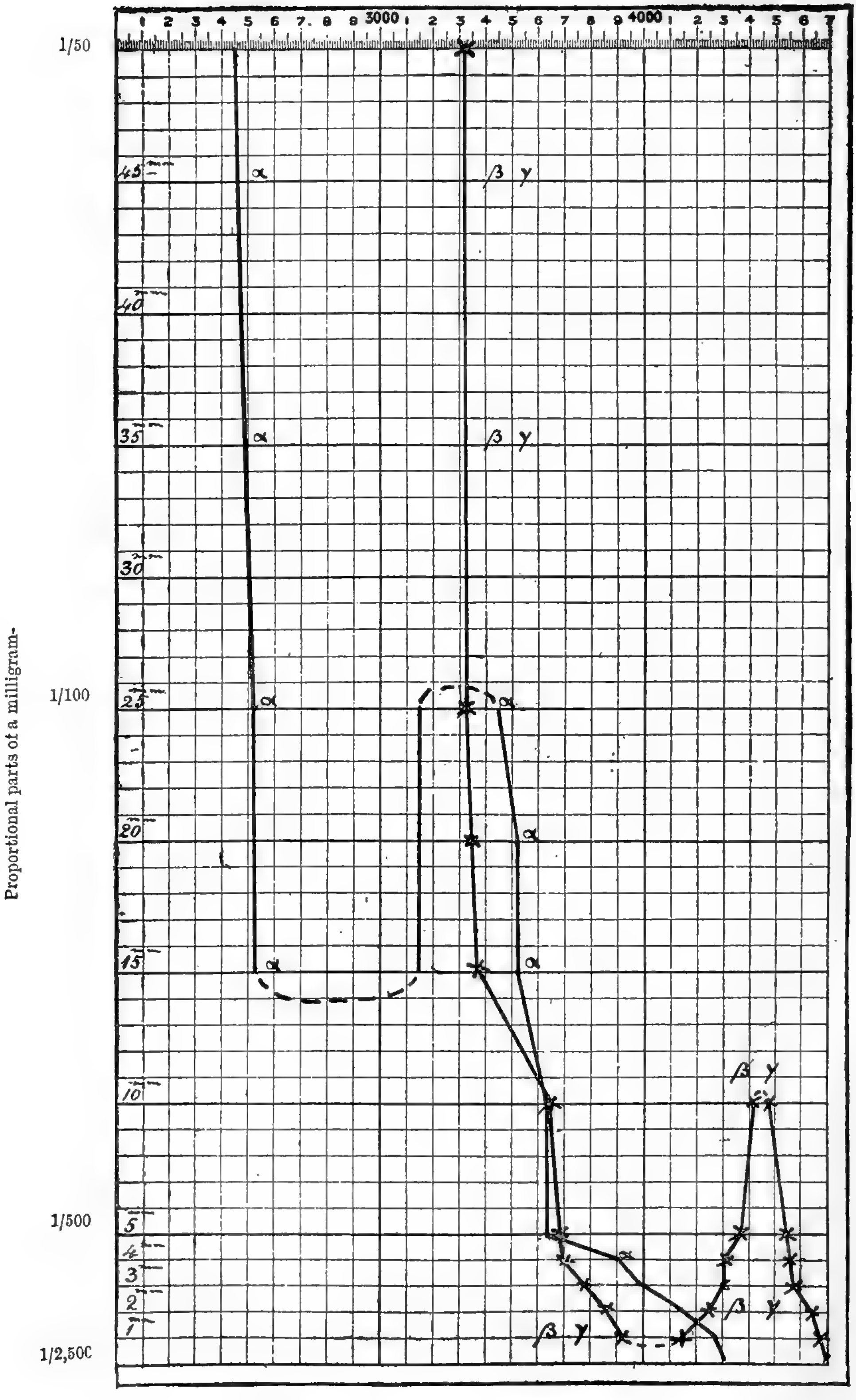
[1] *Loc. cit.*

[2] Hartley, Dobbie, and Paliatseas, *Trans. Chem. Soc.*, vol. lxxvii.

[3] Sandmeyer, *Ber.*, 1886, **19**, 2650.

[4] Bender, *Ber.*, 1886, **19**, 269.

Scale of Oscillation Frequencies.

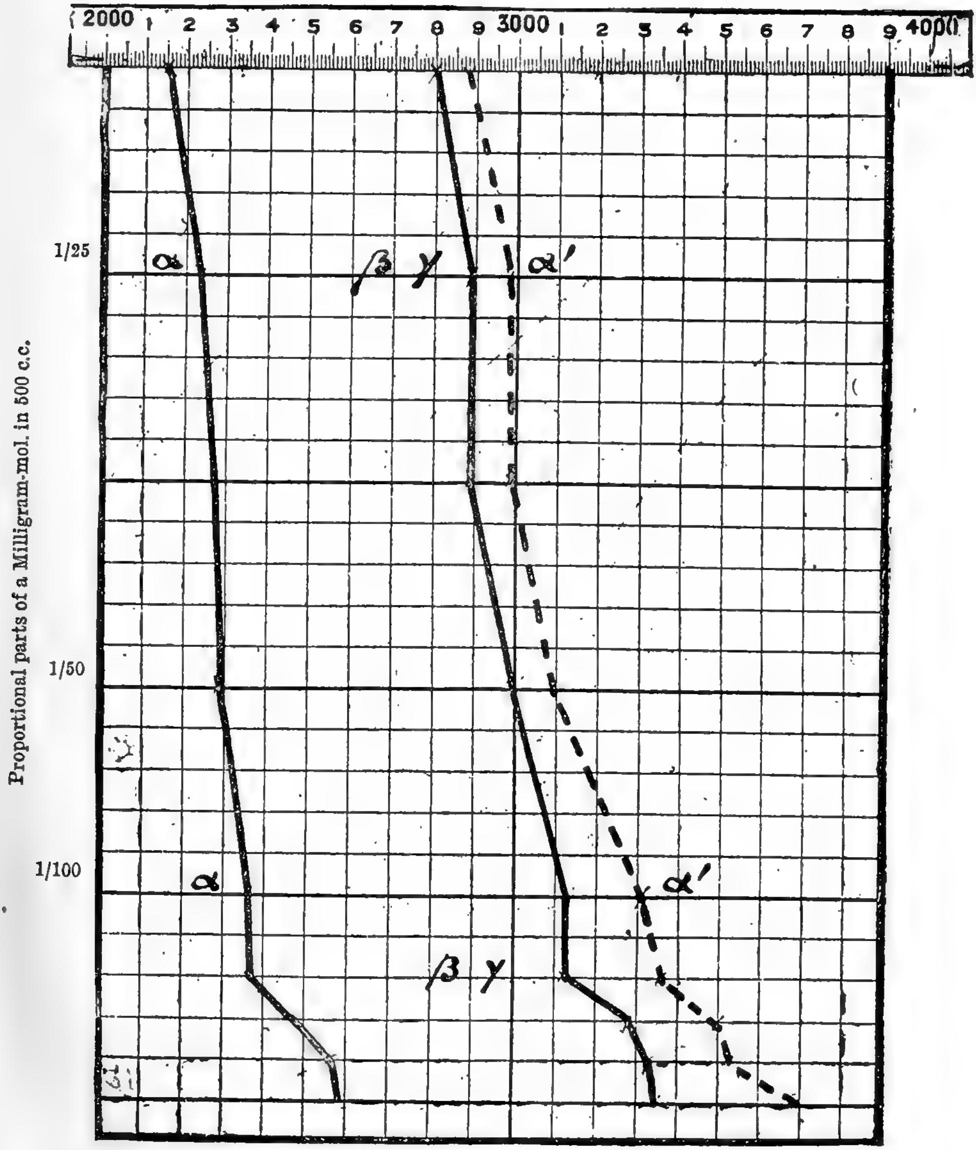


Curves of Molecular Vibrations.

Ethyl α-, β-, and γ-dibenzoylsuccinates. The curves for the β- and γ-esters are identical, and are indicated by stars upon the line at points where measurements of the spectra were made. The curve of the α-ester is indicated by α.

chloride of ethyl *o*-aminophenol. Its structural formula is therefore $C_6H_4<{N(C_2H_5) \atop O}>CO$.[1] The ether prepared by the second method, on

Scale of Oscillation Frequencies.



Curves of Molecular Vibrations.

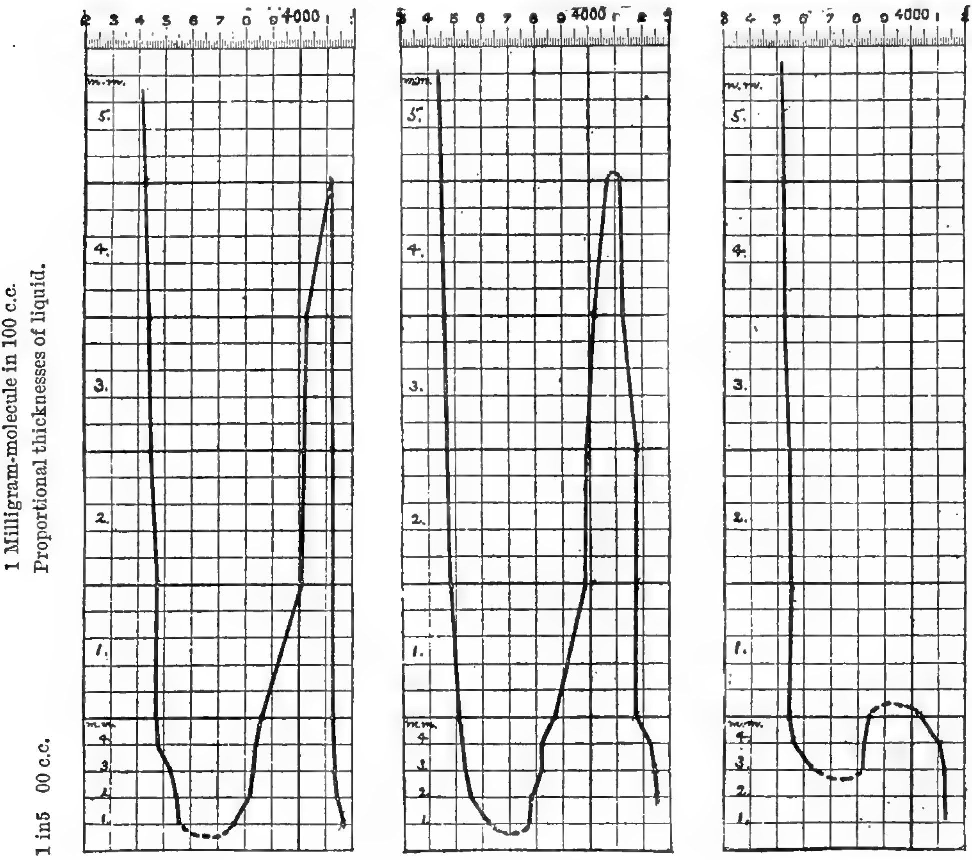
Ethyl α-, β-, and γ-dibenzoylsuccinates. α and α′ are the curves of the α-ester, the former when the substance was freshly prepared, the latter when it had been kept for three weeks. The curves of the β- and γ-esters are identical, and are shown as one, β, γ.

treatment with concentrated hydrochloric acid, yields *o*-oxycarbanil. It is therefore a lactim of the constitution $C_6H_4<{N \atop O}>C \cdot OC_2H_5$.

[1] Bender, *loc. cit.*

As in the similar cases of isatin and carbostyril, the chemical evidence leaves the question of the constitution of *o*-oxycarbanil itself undecided. On the one hand, its formation by the distillation of *o*-aminophenyl ethyl carbonate is most easily explained on the assumption that it has the

Scale of Oscillation Frequencies.



Lactam or ketonic ether. *o*-Oxycarbanil. Lactim or enolic ether.

Curves of Molecular Vibration.

ketonic or lactam constitution, and that the reaction takes place according to the equation

$$C_6H_4{<}\begin{matrix}NH_2\\ O\cdot CO\cdot OC_2H_5\end{matrix} = C_6H_4{<}\begin{matrix}NH\\ O\end{matrix}{>}CO + C_2H_5\cdot OH.$$

This view is supported by the fact that it forms a well-defined compound with phenylhydrazine.[1] On the other hand, its direct formation from the lactim ether by the action of hydrochloric acid seems to point to the enolic or lactim structure as being the more probable. It is, however, now generally admitted that arguments based on chemical reactions are inconclusive in cases such as that under consideration, where shifting of a hydrogen atom may easily take place.

[1] Bender, *loc. cit.*

The present investigation was undertaken with the view of ascertaining whether a comparison of the absorption spectra of the two ethers with the absorption spectra of *o*-oxycarbanil would, as in the cases of isatin and carbostyril,[1] yield results from which the constitution of the parent substance might be inferred. Assuming that one or other of the ethers differs from *o*-oxycarbanil only in the substitution of the alkyl group for an atom of hydrogen, the constitution of the two substances being otherwise identical, we should expect the absorption spectra of the parent substance and this ether to be practically the same. On the other hand, the ether which differs in constitution from the parent substance should give a different spectrum. Groenvik [2] gives 136–138°, Sandmeyer 137°, and Bender 141°, as the melting-point of *o*-oxycarbanil. Although, apart from this slight difference, there was no reason to doubt the identity of the substances obtained by these chemists, we thought it well to examine specimens prepared independently by two different methods and selected for the purpose, the substances obtained by fusion of *o*-aminophenol with urea and by the decomposition of the lactim ether with hydrochloric acid. We found that the two specimens when heated side by side in capillary tubes behaved in exactly the same way, softening at 137° and melting completely at 139°·5. Solutions of the two specimens gave identical spectra.

The spectra of *o*-oxycarbanil and of the lactam ether are almost identical. The amount of general absorption is practically the same in both, and the spectra of both substances show a well-marked absorption band occupying the same position and persisting, in both cases, through the same range of dilution. The spectra of the enolic ether, on the other hand, show a smaller amount of general absorption, and the absorption band does not appear until a much greater degree of dilution is reached than is required to bring out the band in the other two substances. The range of the band of the enolic ester is also very small. The above curves, drawn from the photographs, show very clearly the relations between the spectra of the various substances.

The conclusion to which the investigation leads is that *o*-oxycarbanil has the same structure as the lactam or ketonic ether, or, at all events, that the lactam structure very greatly predominates, if the assumption is made that the parent substance in solution is a mixture of two tautomeric forms. It is worthy of note that in the three cases of this kind which have now been examined the parent substance possesses the ketonic or lactam constitution. *o*-Oxycarbanil, it may be noted, gives no colour reaction with ferric chloride.

The substances used in this investigation were prepared exactly in accordance with the directions given in the papers already quoted. Two distinct preparations of each substance were made and several series of photographs were taken of the absorption spectra of each preparation. No appreciable difference could be detected in the various photographs of the same substance. This is satisfactory evidence of the identity of the compounds, and also of the purity of these particular preparations.

[1] Hartley and Dobbie, *Trans. Chem. Soc.*, 1899, **75**, 640.
[2] *Bull. Soc. Chim.*, 1876 [ii.], **25**, 177.

The Absorption Spectra of Ammonia, Methylamine, Hydroxylamine, Aldoxime, and Acetoxime.[1]

It was shown by L. Soret that commercial ammonia, even after many recrystallisations as sulphate, still shows an absorption band. Hartley and Huntington ('Phil. Trans.,' 1879, Part I., 267) confirmed this observation, and, believing the absorption to be due to traces of some constituent of gas-liquor, examined specimens of what was sold as 'volcanic' ammonia of special purity for analytical purposes. Three separate samples were examined, each measuring half a gallon, with the result that all the rays beyond $1/\lambda$ 2638·2 (λ 2747·7) were absorbed by the strong solution in a cell 15 mm. in thickness. A very distinct absorption band was visible on diluting the liquid with eight volumes of water, and was still seen until sixteen volumes had been added.

This result appeared remarkable in view of the fact that gaseous ammonia, at atmospheric pressure, in a tube 1 metre in length showed no selective absorption, and that ethylamine, even when solutions containing as much as 33 per cent. of the base were examined in cells 25 mm. in thickness, transmitted continuous spectra with very little absorption.

Carbamide also showed no absorption band, but transmitted a continuous spectrum.[2] A 10 per cent. solution of carbamide in a cell 15 mm. in thickness transmits all rays to λ 2140, rays more refrangible than λ 2750 being slightly weakened.

When we remember that practically all the ammonia of commerce is obtained from coal tar, and is liable to contain minute traces of the volatile bases of the pyridine and other series, which can only be completely separated with great difficulty, it is obvious that great care must be taken to obtain chemically pure ammonia for examination before any trustworthy conclusion can be arrived at as to the character of its absorption spectrum.

The following investigation was undertaken with the view of definitely ascertaining whether or not chemically pure ammonia shows selective absorption. An examination of ordinary aqueous ammonia was first made in order to determine the exact position of its absorption band. A tube 150 mm. long was used. With this thickness of layer a solution containing 5 grams of ammonia in 100 c.c. water showed complete absorption beyond $1/\lambda$ 3638 (λ 2749). A layer of the same thickness containing 2·5 grams of ammonia in 100 c.c. gave a continuous spectrum to $1/\lambda$ 3694 (λ 2707), a broad absorption band occupying that portion of the spectrum which lies between $1/\lambda$ 3694 (λ 2707) and $1/\lambda$ 4306 (λ 2322), the spectrum again showing beyond this point. This band is persistent, being still traceable in a solution containing only 0·625 gram of ammonia in 100 c.c. All the samples of commercial ammonia examined showed selective absorption, but by converting the base into ammonium chloride the absorption band was found to become less marked in the spectrum after successive crystallisations of the salt.

In order to try the effect of crystallisation of one of the less soluble salts, ammonia was converted into oxalate and the salt repeatedly

[1] Hartley and Dobbie, *Trans. Chem. Soc.*, vol. lxxvii.

[2] From unpublished experiments on the determination of aromatic substances in urine. See note, *Dublin Journal of Medical Science*, June 1882.—W. N. HARTLEY.

crystallised. The oxalate was distilled with pure potassium hydroxide and the ammonia absorbed in pure distilled water, the spectrum of which was photographed on the same plate as that of the ammonia solution. Much greater thicknesses of liquid were examined than in previous experiments.

A layer 200 mm. thick of a solution containing 10·6 per cent. of ammonia prepared in this way from oxalate transmitted all rays to $1/\lambda$ 3638 (λ2749), but the spectrum was feeble from $1/\lambda$ 2738 (λ 3652) to $1/\lambda$ 3638 (λ 2749). No band was visible. A layer 100 mm. thick transmitted the rays to $1/\lambda$ 4323 (λ 2313), but the spectrum was very feeble beyond $1/\lambda$ 3904 (λ 2561).

From another portion of the purified oxalate the liberated ammonia was passed into optically pure hydrochloric acid; the ammonium chloride recrystallised several times was then examined, the solution of the salt employed having the same thickness of layer and containing the same amount of ammonia as that previously used in determining the position of the absorption band in ordinary ammonia. It now showed no trace of selective absorption, the spectrum being continuous to $1/\lambda$ 4666 (λ 2143) with a scarcely perceptible weakness at the extreme ultra-violet end. Pure ammonia may therefore be obtained without difficulty by the decomposition of a crystallised ammonium salt such as the oxalate.

Ammonia obtained from Hydroxylamine.

Ammonia obtained by the reduction of hydroxylamine was next examined. Hydroxylamine hydrochloride was reduced with a zinc-copper couple and the ammonia distilled into pure hydrochloric acid; the ammonium chloride thus obtained was subsequently purified by recrystallisation.

A layer of 150 mm. of a solution containing 2·5 grams ammonia in 100 c.c. distilled water showed a continuous spectrum to $1/\lambda$ 4411 (λ 2267); the spectrum is weak from $1/\lambda$ 3886 (λ 2573), but there was no indication of selective absorption.

As therefore neither ordinary ammonia, which has been carefully purified by the above method, nor ammonia obtained by the reduction of hydroxylamine, shows selective absorption, we conclude that the absorption band of ordinary ammonia is due to the presence of traces of foreign substances which distil over with it from the gas liquor.

We next endeavoured to ascertain the nature, and estimate the amount, of the impurity to which the band of ordinary aqueous ammonia is due. The position of the band seemed to indicate the pyridine bases as the most likely cause of the absorption, and, in fact, we found that a layer of 150 mm. thick of a solution containing 7·68 grams of pure ammonium chloride (equivalent to 2·5 grams of ammonia) and 0·00001 gram of pyridine in 100 c.c. water, showed almost exactly the same amount and character of absorption as a layer of ordinary aqueous ammonia of the same thickness and strength.

In a further experiment we found that the addition of the same amount of pyridine (in the form of hydrochloride) to 100 c.c. of distilled water produced an identical result, the spectrum being hardly distinguishable from that of ordinary aqueous ammonia.[1] It follows, there-

[1] In this connection it is interesting to note that, although a solution containing 0·000001 gram pyridine in 100 c.c. distilled water no longer showed an actual gap in the spectrum, there was a perceptible weakening of the lines of that portion of the spectrum in which the band of ordinary aqueous ammonia occurs.

fore, that the strong ammonia used (35 per cent. NH_3) contains approximately 0·00014 per cent. pyridine.

Although pyridine is thus shown to be the principal cause of the absorption, minute traces of its higher homologues and of volatile bases of other series are also probably present, as the slight differences between the spectrum of ordinary ammonia and that of pure pyridine appear to indicate.

Methylamine Hydrochloride.

Methylamine was investigated by Hartley and Huntington in cells 50 mm. thick.[1]

An aqueous solution of methylamine was converted into hydrochloride and the salt purified by repeated recrystallisation. A layer 150 mm. thick of a solution containing 25 grams of methylamine as hydrochloride in 100 c.c. distilled water showed practically no absorption. There was a slight weakening of the spectrum towards the ultra-violet end, and one or two of the lines at the extreme end of the ultra-violet were cut off.

Hydroxylamine Hydrochloride.

The hydroxylamine hydrochloride examined was subjected to repeated recrystallisation. It gave no precipitate with platinic chloride in presence of alcohol and ether, and it was therefore assumed to contain no ammonium chloride. The salt is highly diactinic and shows no trace of selective absorption. A layer 150 mm. thick of the solution containing 5 grams of hydroxylamine in 100 c.c. water gives a continuous spectrum to $^1/\lambda$ 4125 (λ 2424). A layer of the same thickness containing 2·5 grams in 100 c.c. water transmits the whole spectrum with the exception of a few of the lines at the extreme end of the ultra-violet.

Acetaldoxime, $CH_3{\cdot}CH{:}N{\cdot}OH$.

Acetaldoxime was prepared in the usual manner by the action of aldehyde ammonia on hydroxylamine hydrochloride, and afterwards purified by fractional distillation until the boiling point was constant: it boiled at 114–115°. In solution this compound shows no selective absorption, but very considerable general absorption. A layer 150 mm. thick of a solution containing 125 grams of acetaldoxime in 100 c.c. water absorbs all lines beyond $^1/\lambda$ 3323 (λ 3009). A layer 25 mm. thick of a solution containing 1 milligram-mol. in 20 c.c. water gives a continuous spectrum to $^1/\lambda$ 3952 (λ 2530), and a layer 1 mm. thick of the same solution shows a continuous spectrum to $^1/\lambda$ 4417 (λ 2264).

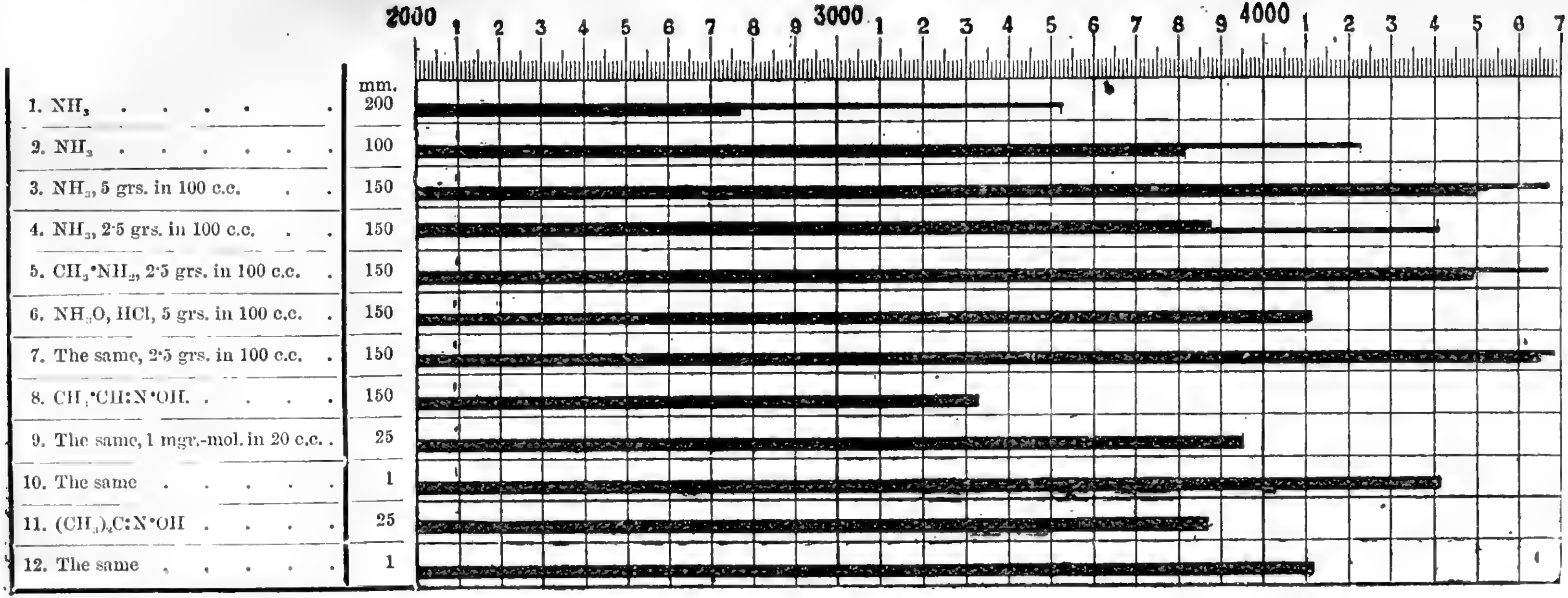
Acetoxime, $(CH_3)_2C{:}N{\cdot}OH$.

Acetoxime was prepared in the usual manner by the action of hydroxylamine hydrochloride on acetone, and was purified by repeated recrystallisation from water: it melted at 59–60°.

Like acetaldoxime, acetoxime shows no selective absorption, but general absorption, which is slightly greater than in the case of the former substance, as was to be anticipated from the presence of an additional methyl group. A layer 25 mm. thick of a solution of ace-

[1] *Phil. Trans.*, 1879, Part I., 267.

Scale of Oscillation Frequencies.



No. 1. Ammonia obtained from recrystallised oxalate containing 10·6 per cent. of NH_3. Thickness 200 mm.
2. The same, rays transmitted through half the thickness.
3. Ammonia as ammonium chloride purified by repeated crystallisations. Thickness 150 mm.
4. Ammonia obtained by the reduction of hydroxylamine examined as ammonium chloride. Thickness 150 mm.
5. Methylamine as hydrochloride. Thickness 150 mm.
6. Hydroxylamine hydrochloride. Thickness 150 mm.
7. The same, half the quantity in solution.
8. Acetaldoxime, 1·25 grs. in 100 c.c. Thickness of 150 mm.
9. The same, 1 milligram-molecule in 20 c.c. Thickness of 25 mm.
10. The same, 1 milligram-molecule in 20 c.c. Thickness of 1 mm.
11. Acetoxime, 1 milligram-molecule in 20 c.c. Thickness of 25 mm.
12. The same, 1 milligram-molecule in 20 c.c. Thickness of 1 mm.

toxime containing 1 milligram-mol. in 20 c.c. shows a continuous spectrum to $^1/\lambda$ 3886 (λ 2573); a layer 1 mm. thick of the same solution to $^1/\lambda$ 4125 (λ 2424).

The substances above referred to afford an excellent illustration of the intimate relation between the character and extent of absorption and the constitution of an organic compound. Ammonia is highly diactinic. The substitution of a methyl group for one of the hydrogen atoms has the effect merely of very slightly increasing the amount of continuous absorption of the most refrangible rays. Again, the substitution of hydroxyl for hydrogen has a similar effect, the group OH, however, having a greater absorptive power than the group CH_3. When we come to acetaldoxime and acetoxime, we find that, regarding them as derivatives of hydroxylamine, the introduction of the more complicated groups $:CH{\cdot}CH_3$ and $:C(CH_3)_2$ respectively for the two remaining hydrogen atoms of the original ammonia molecule, is accompanied by a great increase in the amount of the general absorption. Comparing, however, acetaldoxime with acetoxime, the latter, which differs from the former in the possession of an additional methyl group, shows only slightly greater absorption. This is in harmony with previous observations on CO_2H groups, and the slightly increased absorption caused by the introduction of methyl groups for hydrogen atoms; also the stronger absorption caused by the replacement of hydrogen atoms by hydroxyl radicles.

A diagram drawn to a scale of oscillation frequencies shows at a glance the length of spectrum transmitted by these substances in different proportions, and through different thicknesses.

*The Curves of the Molecular Vibrations of Benz*anti*aldoxime and Benz*syn*aldoxime.*[1]

Benz*anti*aldoxime and benz*syn*aldoxime are now generally represented by the following formulæ :

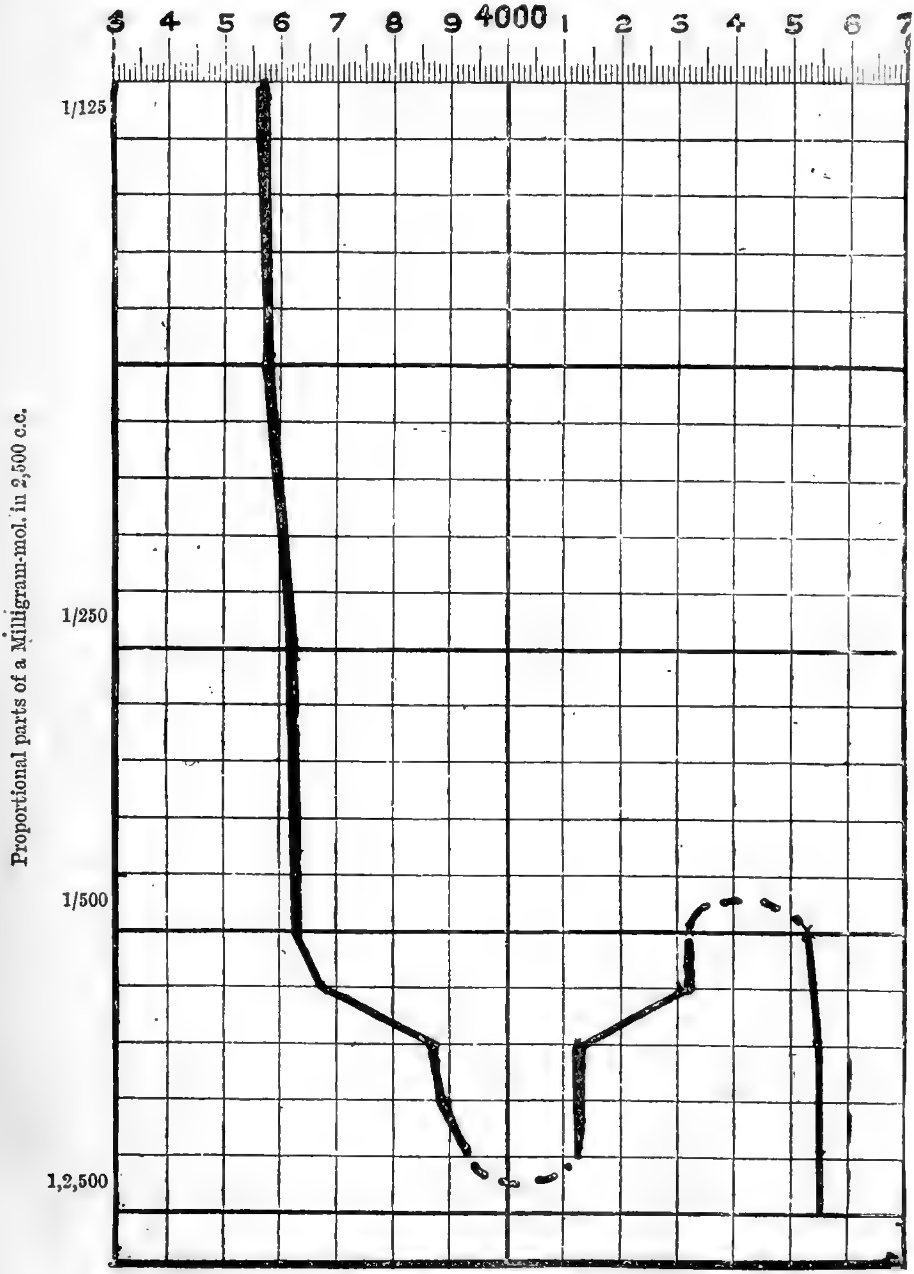
$C_6H_5{\cdot}C{\cdot}H$	$C_6H_5{\cdot}C{\cdot}H$
$\Vert$	$\Vert$
$OH{\cdot}N$	$N{\cdot}OH$
Benz*anti*aldoxime.	Benz*syn*aldoxime.

If these formulæ correctly represent the constitution of the two forms of benzaldoxime and their relation to one another, we should expect both compounds, as stereo-isomerides, to exhibit the same character and amount of absorption. As a matter of fact, we have found that the curves of the molecular vibrations of the two substances in ethereal solution are identical. A layer 25 mm. thick of a solution of either form of the aldoxime containing 1 milligram-mol. dissolved in 100 c. c. of absolute ether, absorbs all rays to $^1/\lambda$ 3323 (λ 3009). A layer 1 mm. thick of a solution containing 1 milligram-mol. in 500 c.c. of ether transmits all rays to $^1/\lambda$ 3638 (λ 2748), and shows an absorption band reaching from $^1/\lambda$ 3638 (λ 2748) to $^1/\lambda$ 4321 (λ 2314). This band is still distinctly traceable in a layer 1 mm. thick of a solution containing 1 milligram-mol. in 2500 c.c. of ether.

[1] Hartley and Dobbie, *Trans. Chem. Soc.*, vol. lxxvii.

The benzaldoximes used in the experiments were prepared by the method given by Beckmann.[1] The benz*anti*aldoxime at 10 and 14 mm.

Oscillation Frequencies.



Curve of Molecular Vibrations.

Benz*anti*aldoxime.
Benz*syn*aldoxime.

pressure respectively was found to have the boiling point given by

[1] *Ber.*, 1890, **23**, 1684.

Luxmoore[1] for those pressures. The benz*syn*aldoxime was photographed immediately after preparation. It was afterwards recovered from the ethereal solution and the melting point redetermined, when it was found that no decomposition had occurred while the photographs were being taken.

These results, which are shown in the above curve, confirm the conclusion previously arrived at, that stereo-isomerides, unlike isomerides which differ in structure, give identical absorption spectra.

The Ultra-violet Absorption Spectra of some Closed Chain Carbon Compounds.[2]

Dimethylpyrazine.

In a previous report[3] we gave the results of the examination of the absorption spectra of thiophen, pyrrole, furfuran, and some of the more important furfuran derivatives. Each of these compounds contains two pairs of carbon atoms doubly linked, the chain being closed by a polyvalent element other than carbon. No trace of selective absorption, such as is shown by benzene, pyridine, and many of their derivatives, could be detected in the spectra of any of these substances.

We have now extended our investigation to 2 : 5-dimethylpyrazine,

$$N \lessdot \begin{matrix} C(CH_3)\cdot CH \\ CH{:}C(CH_3) \end{matrix} \gtrdot N$$

a substance in which not merely one carbon is replaced by nitrogen in the benzene ring, as in pyridine, but two. It thus belongs to a group not previously examined.

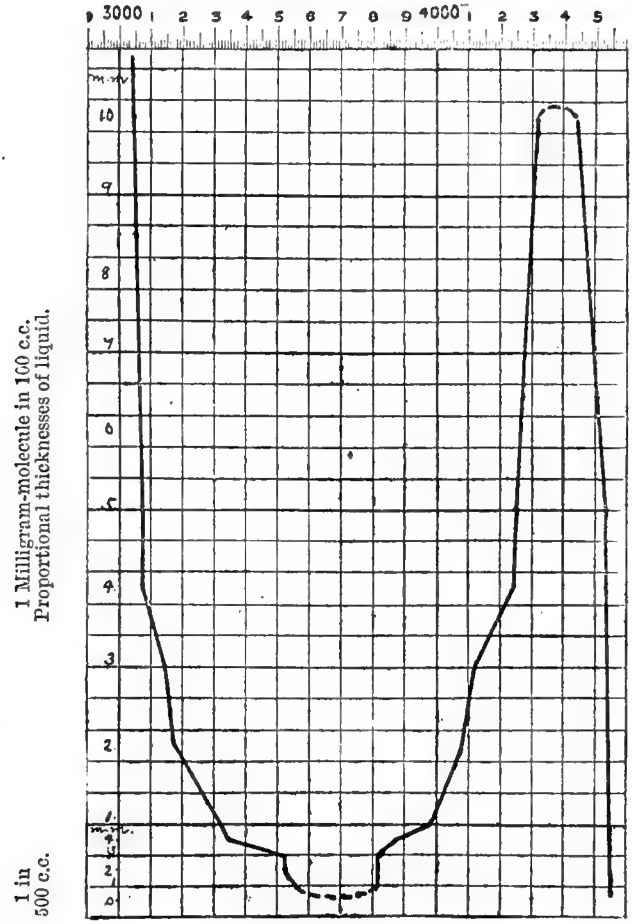
From the analogy between the constitution of this substance and that of pyridine, it was anticipated that it would show a marked selective absorption, and this anticipation proved to be correct. One of the principal reasons for examining a substance of this constitution lay in the fact that whilst pyridine contains the group $\cdot C{:}N\cdot$ once in the benzene structure, dimethylpyrazine contains it twice, and the orginal formula proposed for cyanuric acid[4] contains it three times. Accordingly, if this formula were correct for cyanuric acid and its esters, we should expect that they would exhibit a powerful absorption band, more intense than that of pyrazine, just as that of pyrazine is more intense than that of pyridine. But it has been concluded, from a widely extended experience of the behaviour of such substances under the ultra-violet rays, and particularly from the results of a recent examination of the absorption spectra of its derivatives,[5] that cyanuric acid does not possess this structure, but one in which the acid is represented by a ring composed of three $\begin{matrix} \cdot N\cdot\dot{C}{:}O \\ | \\ H \end{matrix}$ groups, a mode of single linking resembling that of a hydropyridine or of a hydroaromatic group with one carbon replaced by nitrogen;[6] it should not therefore exhibit selective absorption.

The specimen of dimethylpyrazine used in the experiments was pre-

[1] *Trans. Chem. Soc.*, 1896, **69**, 177.
[2] Hartley and Dobbie, *Trans. Chem. Soc.*, 1900, **77**.
[3] *Trans. Chem. Soc.*, 1898, **73**, 598. B.A. Report, 1899.
[4] *Trans. Chem. Soc.*, 1882, **41**, 84.
[5] Hartley, *Proc. Chem. Soc.*, 1899, **15**, 46.
[6] *Phil. Trans.*, Part II., 1885, 519

pared by the reduction of isonitrosoacetone in accordance with the directions given by Gabriel and Pinkus.[1] It boiled constantly at 154–155° (corr.) under atmospheric pressure.

Scale of Oscillation Frequencies.



2 : 5-Dimethylprazine.

A layer 25 mm. thick of a solution of dimethylpyrazine containing 1 mill.-mol. in 100 c.c. of absolute alcohol cuts off all rays beyond $^1/\lambda$ 2994. On reducing the thickness of the layer to 10 mm. an absorption band makes its appearance, reaching from $^1/\lambda$ 3064 to $^1/\lambda$ 4321. This band is very persistent, and is still traceable in a layer 1 mm. thick of a solution containing 1 mill.-mol. of the substance dissolved in 500 c.c. alcohol. The band of dimethylpyrazine is thus both wider and also more persistent than that of pyridine. These results are shown on the curve above.

Hexamethylene.—In the paper already referred to, an account was also given of the absorption spectra of diketohexamethylene. Previous investigations had shown that piperidine[2] and hexachlorobenzene[3]

[1] *Ber.* 1893, **26**, 2206. [2] Hartley, *Trans. Chem. Soc.*, 1885, **47**, 691.
[3] Hartley, *Trans. Chem. Soc.*, 1881, **39**, 153.

exhibit continuous absorption, but show no absorption band, and, as was to be expected, diketohexamethylene, in which the six carbon atoms are united with each other by a single bond, as in hexachlorobenzene and piperidine, likewise showed no bands in the spectrum.

Through the kindness of Professor Sydney Young and Miss Fortey, we have recently been enabled to examine a specimen of pure hexamethylene prepared from Galician petroleum. This substance, in comparison with benzene and pyridine, is highly diactinic. A layer, 60 mm. thick, of a solution containing 1 mill.-mol. dissolved in 20 c.c. of alcohol, transmits all rays up to $^1/\lambda$ 3920, whilst a layer of the same solution, 10 mm. thick, transmits practically the whole spectrum. In none of the photographs of the spectra of this substance could any trace of a banded structure be detected.

Tetrahydrobenzene.—Professor Young and Miss Fortey were also good enough to place a specimen of pure tetrahydrobenzene in our hands for examination. This substance exhibits somewhat greater general absorption than hexamethylene, a layer, 60 mm. thick, of a solution containing 1 mill.-mol. in 20 c.c. alcohol absorbing all rays beyond $^1/\lambda$ 3694, while absorption is still traceable in a layer of the same solution 1 mm. thick. Like hexamethylene, tetrahydrobenzene shows no selective absorption. The examination of these two substances thus confirms the conclusion previously reached, that the banded spectrum is shown only by substances which possess the true benzenoid structure.[1]

Ultra-violet Absorption Spectra of Albuminoids.[2]

The first investigation of albuminoids of animal origin was made by Soret: it included albumen, white of egg, pure albumen, caseine, and serine. Absorption bands occur in their spectra in the following positions:—Albumen (white of egg) λ 2880–2650, pure albumen λ 2948–2572, caseine λ 2948–2572. Serine exhibits a band similar to that of caseine.

In addition to albumen the following substances have been examined:[3]—

(1) Gelatine; (2) maize starch; (3) cane sugar; (4) glucose; (5) yeast water; (6) invertase; and (7) diastase. These are all highly diactinic substances, considering their complex constitution, and they show no absorption bands. It is evident, therefore, that the constitution of albumen, caseine, and serine is very different from that of invertase, diastase, gelatine, starch, glucose, and saccharose.

This was of interest in connection with C. V. Naegeli's theory of fermentation. Naegeli regarded fermentation as a process in which a transference takes place to fermentable matter of the molecular or rather intramolecular vibrations of the constituent substances entering into the composition of living protoplasm whereby the equilibrium of the molecules of the fermentable matter became so disturbed as to cause their resolution into simpler molecules. It appears by no means improbable that the diastatic ferments may have some such action. From this point of view

[1] Hartley, *Trans.*, 1881, **39**, 153.

[2] *Comptes Rendus*, 97, p. 642; also *Archives des Sciences Physiques et Naturelles*, x. p. 139. (L. Soret.)

[3] Hartley, *Trans. Chem. Soc.*, 1887, **51**, 59.

it does not appear likely that a substance of the character of albumen, whose mode of vibration, as shown by its absorption spectrum, differs widely from that of the carbohydrates, could affect the latter, while on the other hand it is possible that the intramolecular vibrations of invertase and diastase might be communicated to saccharose and starch. That the sugars are highly diactinic substances is quite in character with what we know of their constitution and of the spectra of similarly constituted substances.

It is of interest to learn that the albuminoid compounds associated with the carbohydrates are evidently different in constitution from those forms of albumen found in the animal organism. The probability presents itself of these albuminoids being derived from the carbohydrates.

Isomorphous Derivatives of Benzene.—Report of the Committee, consisting of Professor H. A. MIERS (*Chairman*), Dr. W. P. WYNNE, *and* Dr. H. E. ARMSTRONG (*Secretary*). (*Drawn up by the Secretary.*)

THE existence of morphotropic relationships between the crystalline forms of substances which are not isomorphous in the formal sense of the term has of recent years acquired new importance, the purely geometrical work of Barlow [1] and others having demonstrated the superfluity of the old view that the units of the crystalline structure are polymerides of the chemically active fundamental molecule as a means of explaining polymorphism and kindred crystallographic phenomena, whilst Fock [2] has shown, from the study of the partition coefficients of two isomorphous substances in equilibrium in a liquid and a solid solution in contact, that in the case of salts, at all events, the molecular weight in the crystalline state may be that of the fundamental molecule. Moreover the work of Paternò [3] and others on the cryoscopic behaviour of substances possessing constitutions similar to that of the solvent indicates with certainty that isomorphism and morphotropy are phenomena which merge gradually one into the other.

The consideration of facts such as these leads to the conclusion that morphotropy and isomorphism have a common cause, and that this is more likely to be discovered by the crystallographic study of substances showing morphotropic relationships than from the examination merely of materials likely to exhibit isomorphism.

The benzene series offers exceptional opportunities for the study of such questions; indeed, it is remarkable that the publication of Groth's important memoir,[4] calling attention to the existence of morphotropic relationships between benzene derivatives, has not acted as an incentive to really systematic work on the subject.

The two investigations to be referred to form part of a series which are being carried on in the chemical department of the Central Technical College, South Kensington, in order, as far as possible, to determine the effect on the crystalline form of certain definite changes in the composition. The work will include the determination of the molecular volumes

[1] *Proc. Roy. Dub. Soc.*, 1897, viii. 527.
[2] *Zeits. f. Kryst.*, 1897, xxviii. 337.
[3] *Gazzetta*, 1895, xxv. 1, 411.
[4] *Pogg. Ann.*, 1870, **141**, 31.

and of the melting-point curves of mixtures of the morphotropically related compounds.

Morphotropic Relationships between Formanilide and its Substitution Derivatives.

In order to determine the morphotropic effect of substitution upon the crystalline form of formanilide the simple anilides of the composition $C_6H_5.NH\ (CO.X)$ (X=H, Me, Et, Pr, &c.) as well as several of their alkyl derivatives, and also a number of the mono- and di-halogen derivatives, have been crystallographically examined by Mr. L. P. Wilson; a list of the compounds measured is given in the accompanying table, in which the geometrical constants are also indicated. It is evident that a progressive change in the structural dimensions occurs as each series is traversed, although in most cases this only becomes obvious on rearranging the axial ratios, and sometimes on taking simple multiples of the ratios. The form in which the axial ratios are compared is indicated in the second column.

			β.	
	I.		° ′	
Formanilide	$a : b : c$	= 2·188 : 1 : 2·403	90 54	M
Acetanilide	$c : b : a$	= 2·0670 : 1 : 0·8488	90	O
Propionanilide	$c : b : a$	= 2·1665 : 1 : 1·0428	90	O
Butyranilide	$3a : b : 2c$	= 2·1663 : 1 : 1·3788	90	O
	II.			
Acetanilide	$c : b : a$	= 2·0670 : 1 : 0·8488	90	O
Methylacetanilide . .	$2c : b : a$	= 0·7906 : 1 : 0·8494	90	O
Ethylacetanilide . .	$c : b : a$	= 1·0064 : 1 : 0·8401	90	O
Propylacetanilide . .	$c : b : a$	= 1·3264 : 1 : 0·8410	90	O
	III.			
P.-brom-formanilide . .	$c : b : 2a$	= 1·4100 : 1 : 2·2056	90	O
,, acetanilide . .	$a : b : c$	= 1·3904 : 1 : 0·7159	90	O
,, propionanilide .	$3a : b : c$	= 1·3400 : 1 : 0·8948	90	O
	IV.			
P.-brom-acetanilide . .	$a : b : c$	= 1·3904 : 1 : 0·7159	90	O
,, methyl acetanilide	$a : b : c$	= 1·5546 : 1 : 0·9719	70 7	M
,, ethyl ,, .	$a : b : c$	= 1·4063 : 1 : 1·5686	95 35	M
	V.			
P.-chlor-acetanilide . .	$a : b : c$	= 1·3263 : 1 : 0·6804	90	O
P.-brom ,, . .	$a : b : c$	= 1·3904 : 1 : 0·7159	90	M
P.-iodo ,, . .	$a : b : c$	= 1·4185 : 1 : 0·7415	90 29	M
	VI.			
2 : 4 dichlor-acetanilide .	$a : b : c$	= 0·8263 : 1 : 0·6828	77 33	M
,, chlorbrom-acetanilide	$a : b : c$	= 0·8144 : 1 : 0·6722	77 40	M
,, bromchlor ,, .	$a : b : c$	= 0·8214 : 1 : 0·7074	77 46	M
,, dibrom ,, .	$a : b : c$	= 0·8131 : 1 : 0·6895	78 24	M

In series 1, although the first member is monosymmetric, whilst the others are orthorhombic, a well-marked morphotropic similarity in the magnitudes of the ratio a/b is observed to follow the displacement of the hydrogen atom in the acidic group by Me, Et or Pr. The effect of displacing the aminic hydrogen atom by Me, Et or Pr is less, as is shown by

an inspection of series 2; in this case the ratio c/b is more nearly constant throughout the series than in the case in series 1. In series 3, obtained by displacing the acidic hydrogen atom in parabromoformanilide by either Me or Et, the ratio a/b again shows approximate constancy. No simple relationship is observable between parabromacetanilide and its methyl or ethyl derivative. Parabrom- and paraiod-acetanilide are isomorphous; the corresponding chloro-derivative is not isomorphous with them, although it bears a marked morphotropic relationship to them.[1] Group 6 forms a well-marked isomorphous series.

Otten[2] has observed that butyranilide is dimorphous, but has not examined the substance in great detail; a study of this compound has shown that the dimorphism is of a very remarkable character. At ordinary temperatures the anilide separates from alcoholic solutions in large transparent crystals of pyramidal habit, which are distinctly orthorhombic, showing a characteristically orthorhombic interference figure of small optic axial angle. The axial ratios of such crystals are a : b : c=0·6920 : 1 : 0·6792. On preserving crystals which had been measured at a constant temperature of 8° to 11° they have been found to change gradually, and in the course of three months completely, into tetragonal crystals, without at the same time losing their brilliancy and transparency. The axial ratio a : c=0·6652 : 1 in these crystals; they exhibit the characteristic uniaxial interference figure. On preserving the definitely tetragonal material at 30° for eighty days the reverse change occurs, the crystals becoming orthorhombic and biaxial, although the axial ratios never revert to quite their original values. The density of the orthorhombic form is 1·130, whilst that of the tetragonal form is 1·139.

The molecular volumes of several of the anilides have been determined, with the object of examining the relations between the topic axial ratios of Muthmann;[3] the ordinary axial ratios seem, however, in most cases to express the morphotropic relationships just as clearly as the topic ratios.

Iso- and Poly-morphous substituted Benzene-sulphonic Chlorides and Bromides.

It has already been stated[4] that the sulphonic chlorides and bromides derived from the 1 : 3 : 4 dihalogen-benzene-sulphonic acids together form an isotrimorphous series. Dr. Jee's further study of this group has led to important results. The series includes anorthic, orthorhombic, and monosymmetric terms, in the manner shown in the following table :—

Orientation				Crystallographic Systems		
—	1	3	4	Anorthic	Orthorhombic	Monosymmetric
I.	Cl	Cl	SO_2Br	stable	—	—
II.	Cl	Br	SO_2Br	stable	—	—
III.	Br	Cl	SO_2Br	stable	—	—
IV.	Br	Br	SO_2Br	labile→	stable	—
V.	Br	Br	SO_2Cl	(labile)→	stable	labile
VI.	Br	Cl	SO_2Cl	—	stable	labile
VII.	Cl	Br	SO_2Cl	—	labile→	stable
VIII.	Cl	Cl	SO_2Cl	—	labile→	stable

[1] Compare Fels, Dissert., Leipzig, 1900.
[2] *Zeits. f. Kryst.* xvii. 391.
[3] *Zeits. f. Kryst.*, 1894, xxii. 497.
[4] *B.A. Report*, 1899, p. 688.

Of these eight substances, three are stable in the anorthic system, three in the orthorhombic system, and two in the monosymmetric system. Change of the one form into the other has been observed in four cases (IV., V., VII., VIII.) on allowing the fused substance to cool on a microscopic slide; the direction of the change in each case is indicated in the table by an arrow. A labile anorthic crystalline form of dibromo-benzene-sulphobromide (IV.) has been obtained from solution; and it has been found that each of the four sulphochlorides (V.–VIII.) can be caused to crystallise in the alternative system by admixture with a sulphochloride which usually separates in that system. It has been possible to determine the symmetry of all the forms referred to in the table by crystallographic measurement, with the single exception of the labile anorthic form of dibromo-benzene-sulphochloride, but the existence of this form is indicated by the dimorphous change which occurs on cooling from the melting point to the atmospheric temperature.

The detailed study of such a series of isomorphs—especially of the melting points of mixtures and of the conditions which determine the separation of the various crystalline forms—will be of importance, as it is likely to furnish information of value in discussing the phenomena presented by igneous rocks containing isomorphous minerals.

The investigation has been extended by Dr. Jee to the corresponding derivatives of the 1 : 3 : 5 dihalogen-benzene-sulphonic acids. The results obtained indicate the existence of an isodimorphous series having no apparent similarity with the 1 : 3 : 4 series. One of the members of this new series—1 : 3 : 5 dibromo-benzene-sulphobromide—has been obtained in two distinct crystallographic forms, both belonging to the monosymmetric system. At atmospheric temperature one of these forms is labile and isomorphous with the corresponding sulpho-chloride, and with 1 : 3 : 5 bromo-chlorobenzene-sulphochloride. The stable form of 1 : 3 : 5 dibromo-benzene-sulphobromide, on the other hand, is isomorphous with 1 : 3 : 5 bromo-chlorobenzene-sulphobromide. The derivatives of the symmetrical dichloro-acid have not yet been satisfactorily measured.

Even in their present incomplete form these results are of considerable importance as showing the manner in which the occurrence of polymorphism may render obscure otherwise well-marked isomorphous or morphotropic relationships. Apparently a substance may crystallise in a whole series of different forms, A, B, C, D, the particular form obtained under ordinary conditions being the form stable at the temperature at which the crystals are grown. Another substance, the immediate homologue of the first in an isomorphous series, can also assume crystalline forms corresponding with A, B, C, D, &c., but the particular form stable at ordinary temperatures will not be the same as before, owing to the non-correspondence of the transition temperatures. Consequently the first member of an isomorphous series may crystallise in a form of type A, the second member in a form of type B, the third of type C, and so on, the isopolymorphism completely masking the isomorphism.

The Electrolytic Methods of Quantitative Analysis.— Sixth Report of the Committee, consisting of Professor J. EMERSON REYNOLDS (*Chairman*), Dr. C. A. KOHN (*Secretary*), Professor P. FRANKLAND, Professor F. CLOWES, Dr. HUGH MARSHALL, Mr. A. E. FLETCHER, *and* Professor W. CARLETON WILLIAMS.

THE work of the Committee, appointed in 1894, has hitherto included a complete bibliography on electrolytic analysis up to the end of 1894 and experimental investigations on the electrolytic determination of antimony, bismuth, cobalt, nickel, zinc, and the separation of antimony and tin.

The present report deals with further work on the determination of bismuth, and with the determination of iron, its separation from manganese, and the application of the electrolytic method to the determination of iron in organic products.

These experiments cover some of the most important applications of electrolytic analysis which required further investigation, and the Committee propose to conclude their work with the present report.

The more recent bibliography of the subject has been summarised by Neumann.[1] The Committee would also refer to Neumann's book on electrolytic analysis,[2] which has been issued since their bibliographical report, and an English translation of which has been prepared by Kershaw ;[3] also to the annual reports on electrolytic analysis published in the 'Jahrbuch für Electrochemie.'

The Determination of Bismuth (Part II.) By Professor J. EMERSON REYNOLDS, *D.Sc., M.D., F.R.S., and* W. C. RAMSDEN.

In a previous report (1896) it was shown :—

1. That carefully spun platinum dishes were better suited for use as negative electrodes than any other of the various forms experimented with.

2. That irregular results only could be obtained with simple bismuth-nitrate solutions containing varying proportions of free nitric acid ; but that good determinations were more easily made in solutions of the sulphate when electrolysed by currents beginning at 0·08 and finishing at not more than 0·2 ampere.

3. That the best results were obtained in presence of metaphosphoric acid and of citric acid, both of which controlled deposition in a very marked manner.

4. That citric acid is quite as effective as metaphosphoric acid and possesses the additional advantage that the metal can also be separated in satisfactory condition from ammoniacal solutions of the citrate.

Two questions remained for consideration, viz. (*a*) the separation of bismuth from strong but simple solutions, and (*b*) from solutions containing other metals.

[1] *Chem. Zeits.* 1900, 24, 455.
[2] *Theorie u. Praxis der analytischen Electrolyse der Metalle*, 1897.
[3] *The Theory and Practice of Electrolytic Methods of Analysis*, 1898.

The work under the first head was in progress at the time the former part of the report was published by one of the present writers and Mr. Bailey, and was subsequently carried as far as seemed desirable. The results obtained with moderately strong solutions of bismuth were very unsatisfactory, even in presence of much citric acid and when treated with all the care indicated by our former experience. We then proceeded to determine the major limit of concentration at which good determinations can be made.

Taking 150 c.c. as the most convenient volume for use in the electrolytic capsules employed, we found that excellent results could be obtained in presence of 2·5 gr. of citric acid, so long as the weight of metal in 150 c.c. did not exceed 0·22 gr. With stronger solutions we failed to obtain satisfactory reguline deposits, even when the proportion of citric acid was increased and the current at the commencement of the operation was reduced to 0·005 ampere, so that the rate of deposition should be very slow.

We therefore arrived at the conclusion that 150 c.c. of bismuth solution should not contain more than about 0·22 gr. of metal in the form of nitrate or sulphate, and that 2·5 to 3·0 gr. of pure citric acid suffice to control the deposition, provided the initial current used and acting for some hours be about 0·01 ampere, increased at the end, and for a short time, to 0·15 or 0·2 ampere.

Separation of Bismuth from other Metals.

Extended experience in the electrolytic determination of bismuth in simple solutions of varying strength led us to doubt that the purely electrolytic separation of the element from other metals would prove satisfactory. The results obtained by the present writers have justified this anticipation.

The least unfavourable determinations of bismuth in such mixtures with other metals as would probably be met with in practice were those obtained with cadmium and zinc; but even in these theoretically favourable cases it was found that, however feeble the currents used, the deposited bismuth carried down sensible amounts of the much more positive metals. The method of experimenting was as follows :—

A carefully measured volume of a bismuth-nitrate solution known to contain 6·018 gr. of metal per litre, in the form of nitrate, was placed in a platinum capsule. The special treatment to be applied in each case was then carried out; pure citric acid added, the solution diluted with water to about 150 c.c., and a current passed through the liquid of such strength (generally 0·01 ampere) as to secure a good reguline deposit of bismuth. The whole of the metal was seldom separated under fifteen to twenty hours, and was hastened at the end by passing a current of about 0·1 ampere for a short time. The contents of the capsule were then washed with water and alcohol, and the vessel dried and weighed.

Of the experiments recorded below, the first three aimed at fixing the degree of accuracy with which bismuth could be electrolytically separated from the particular simple nitrate solution used in presence of citric acid. The citric acid used in work of this kind should be tested for lead, &c., before use, as samples are sometimes met with which contain metallic impurities. The total volume of liquid used was the same in these as in all other cases, viz. about 150 c.c.

Experiment A. 0·2407 gr. of bismuth in solution + 3 gr. of citric acid gave after eighteen hours a fairly firm reguline deposit, which weighed 0·2382 gr.

Experiment B. 0·1805 gr. of bismuth gave under the same conditions a perfectly firm deposit weighing 0·1807 gr.

Experiment C. 0·1805 gr. of bismuth with 2·5 gr. of citric acid gave an excellent deposit of 0·1804 gr.

The concentration of the solution in experiment A was too high, as already pointed out; but the results obtained in the weaker solutions used in B and C were as good as could be obtained in any determinations of this class.

The effect of the addition of sulphuric acid is shown in the next three experiments.

Experiment D. 0·1805 gr. of bismuth in solution with 0·5 c.c. of pure freshly distilled H_2SO_4 and 2 gr. of citric acid gave, after twenty hours, as good a deposit as in B, and weighed 0·1807 gr.

Experiment E. 0·1805 gr. bismuth with the same volume of H_2SO_4, but with 4 gr. of citric acid. The metal came down very slowly from solution, but in good condition, even when a stronger current was used for a longer time than usual: at the end the weight obtained, after twenty-six hours, was 0·1801 gr. The proportion of citric acid used was therefore needlessly large.

Experiment F. 0·1504 gr. of bismuth in solution, 1 c.c. of H_2SO_4 and 2 gr. of citric acid gave a good deposit, which weighed 0·1507 gr.

Therefore good results can be obtained in presence of much more free sulphuric and nitric acids than would probably be present in actual analysis, or could be separated from mixed sulphates.

In the remaining tests cadmium or zinc salts were present.

Experiment G. 0·2106 gr. of bismuth in solution, 1 c.c. of H_2SO_4, 2 gr. of citric acid, and 0·125 gr. of cadmium in the form of sulphate. Result: 0·2687 gr. The deposit easily oxidised and contained some cadmium, though the current was kept as low as possible throughout.

Experiment H. 0·2106 gr. of bismuth in solution, in all respects as last, gave 0·2986 gr. of deposit containing cadmium.

Experiment I. 0·1805 gr. of bismuth as last, except that only 0·5 c.c. of H_2SO_4 was added, gave a fair deposit, but contained cadmium and weighed 0·2096 gr.

Experiment J. 0·1925 gr. bismuth; treated solution as last, but with 4 gr. of citric acid, gave 0·2340 gr. deposit, easily oxidised as in the other cases, and cadmium was found in the film.

The results with zinc were similar; for example:—

Experiment K. 0·1504 gr. bismuth; the solution containing zinc in the form of sulphate instead of cadmium, 0·5 c.c. H_2SO_4 and 2 gr. of citric acid. The metal separated in fair condition, but was easily oxidised; it weighed 0·1642 gr. and contained traces of zinc.

Experiment L. 0·1805 gr. bismuth as last, and with zinc sulphate, gave 0·1851 gr., and contained zinc also.

Therefore, while bismuth can be determined electrolytically with accuracy in simple and dilute solutions containing citric acid, and even relatively large proportions of free nitric and sulphuric acids, we are unable to recommend its electrolytic separation from any of the metals with which we have experimented.

The best course, in our opinion, is to separate the bismuth by any of the well-known methods in the form of hydroxide, to dissolve the latter in sufficient nitric acid, and, after necessary dilution with addition of citric acid, to electrolyse, with the precautions already described.

The Determination of Iron. By CHARLES A. KOHN, *M.Sc., Ph.D.*
Bibliography.

Author	Journal	Year	Volume	Page	Composition of Electrolyte
Avery, S., and Dales, B.	Ber.	1899	32	64	Ammonium oxalate. Sodium citrate. Ammonium metaphosphate.
Avery, S., and Dales, B.	Ber.	1899	32	2233	Ammonium oxalate.
Brand, A.	Zeits. anal. Chem.	1889	28	581	Sodium pyrophosphate and ammonium carbonate.
Classen, A., and Reis, M. A.	Ber.	1881	14	1622	Ammonium oxalate.
Classen, A.	Ber.	1894	27	2060	Potassium and ammonium oxalates.
Gibbs, W.	Amer. Chem. J.	1891	13	570	Sulphate; *as amalgam.*
Heidenreich, M.	Ber.	1896	29	1585	Sodium citrate and citric acid.
Kohn, C. A., and Woodgate, J.	J. Soc. Chem. Ind.	1889	8	256	Potassium and ammonium oxalates.
Kollock, L. G.	J. Amer. Chem. Soc.	1899	21	911	Sodium citrate and citric acid.
Luckow, C.	Zeits. anal. Chem.	1880	19	1	Ammonium citrate and citric acid.
Moore, T.	Chem. News	1886	53	209	Phosphoric acid.
Nicholson, and Avery, S.	Amer. Chem. J.	1896	18	654	Tartaric acid and ammonium hydrate. Borax and ammonium oxalate.
Parodi, G., and Mascazzini, A.	Zeits. anal. Chem.	1879	18	587	Acid ammonium oxalate.
Rüdorff, F.	Zeits. angew. Chem.	1892	—	197	Ammonium oxalate.
Thomälen, H.	Zeits. Electrochem.	1894	1	304	Ammonium oxalate.
Smith, E. F.	Amer. Chem. J.	1888	10	330	Sodium citrate and citric acid.
Smith, E. F., and Muhr, F.	J. Analyt. & App. Chem.	1891	5	488	Tartaric acid and ammonium hydrate.
Verwer, H., and Groll, F.	Ber.	1899	32	806	Ammonium oxalate.
Vortmann, G.	Monatsh. Chem.	1893	14	536	Sodium potassium tartrate and sodium hydrate.
Wolman, L.	Zeits. Electrochem.	1897	3	542	Ammonium oxalate.

The electrolytic methods for the determination of iron can in no way be regarded as comparable with the usual volumetric and gravimetric methods in their general applicability. Under special circumstances, however, they may be found advantageous, especially in the determination of relatively small quantities of iron in organic products, an application which has been specially studied in the subjoined experiments.

Of the various methods proposed, that in which the metal is deposited from a solution of the double ammonium oxalate, first suggested by Parodi and Mascazzini, and subsequently worked out by Classen, is the most reliable. When separated from a citrate or tartrate solution, the precipitated iron contains a considerable proportion of carbon, and the deposition from phosphoric acid or ammonium pyrophosphate solution is too slow to be of practical value ; further, it necessitates a high current density, and the introduction of phosphates into the solution is an obvious disadvantage from an analytical standpoint.

The experiments have therefore been restricted to the investigation of the deposition of iron from the solution of the double ammonium oxalate. They may be conveniently grouped under the following heads :—

1. *The conditions under which iron is deposited from ammonium oxalate solution and the most favourable conditions for its electrolytic determination.*

2. *The influence of ammonium chloride on the electrolytic determination of iron.*

3. *The complete separation of the iron when deposited from ammonium oxalate solution : the sulphocyanide reaction for iron under the conditions of the experiments.*

4. *The presence of carbon in iron deposited from ammonium oxalate solution and the determination of its amount.*

5. *The electrolytic separation of iron and manganese in ammonium oxalate solution.*

6. *The electrolytic determination of iron in urine and other animal products.*

1. *The Conditions under which Iron is deposited from Ammonium Oxalate Solution, and the most favourable Conditions for its Electrolytic Determination.* By CHARLES A. KOHN, *M.Sc., Ph.D., and* H. H. FROYSELL.

Classen recommends the addition of 6 to 8 gr. of ammonium oxalate per gr. of iron in 150–175 c.c. of solution, and conducts the electrolysis with a $C.D._{100}$ of 1·0 to 1·5 ampere and 3 to 4 volts in a warm solution (40°–60° C.). Nitrates, if present, must be removed by repeated evaporation with sulphuric or hydrochloric acid ; free sulphuric acid can be neutralised by ammonium hydrate ; any free hydrochloric acid is preferably removed by evaporation on the water-bath. The complete deposition of the iron is tested with potassium sulphocyanide, after acidifying with hydrochloric acid ; 0·2 to 0·3 gr. of iron is deposited in three to four hours.

In a later paper Classen states that the most favourable condition for the deposition of iron is with a current $N.D._{100}=1·5$ ampere at the ordinary temperature. Neumann [1] adds that weaker currents (0·3 to 0·5 ampere) can be used, but then a larger proportion of ammonium oxalate must be

[1] *Theorie u. Praxis der analytischen Electrolyse der Metalle*, p. 114.

added and the current increased to 1·0 ampere at the end of the determination to ensure the precipitation of the last portion of the iron. According to Wolman, eight to ten hours are necessary for the deposition of 0·15 to 0·30 gr. of iron with a $C.D._{100}=0·3$ to 1·0, and finally to 1·5 ampere, and an E.M.F. of 4 volts at 50° C. The majority of the results recorded by this method are slightly low, on an average 0·2 to 0·6 per cent. on the weight of iron taken.

Variations in current and in the proportion of ammonium oxalate added constitute the only real differences in the conditions of deposition recommended, and they bear on the one practical difficulty of the method—the prevention of the separation of any ferric hydrate during the electrolysis. As pointed out in a previous report (1896) on the electrolytic determination of tin in ammonium oxalate solution, the electrolyte gradually becomes alkaline, owing to the decomposition of the oxalate and the formation of ammonium carbonate; in presence of a sufficient excess of ammonium oxalate the iron will still remain in solution after the latter is alkaline, but otherwise ferric hydrate separates out and oxalic acid must be added from time to time during the electrolysis to redissolve it. Such addition of oxalic acid renders it necessary to watch the experiment; a further drawback is that the quantity of ammonium oxalate solution necessary leaves little room for any further addition of liquid in an ordinary dish of 175 c.c. to 200 c.c. capacity. Hence the ammonium oxalate must outlast the deposition of the iron if an addition of oxalic acid is to be avoided. A series of experiments were, therefore, first arranged in which the time necessary for the solution to become alkaline, the proportion of metal deposited up to alkaline reaction, and the proportion subsequently deposited, were noted.

A ferric chloride solution of known strength was used, made up from pure ferric oxide, the method of working being as follows:—The slight excess of hydrochloric acid in the measured portion of the solution was first neutralised with a few drops of ammonium hydrate, oxalic acid solution added to acid reaction, and the whole then added to the ammonium oxalate solution. The additional oxalic acid recorded was either added to the original solution or at intervals during the electrolysis. The current density, $C.D._{100}=1·0$ to 1·5 ampere, and electromotive force of 3·5 to 4·0 volts employed in these first experiments are the values hitherto regarded as the most favourable for the deposition of iron. Both warm and cold solutions were tried. The ammonium oxalate solution contained 40 gr. per 1,000 c.c.; the oxalic acid solution 80 gr. per 1,000 c.c.

Platinum dishes of about 200 c.c. capacity were used as the cathode and bored platinum discs as the anode; the circuits and measurements were arranged as described in the Committee's third report (1896).

The following results illustrate the conclusions to be drawn from this series of experiments:—

Series I.

In experiments 1, 2, 3, 4, and 5, 10 c.c. of oxalic acid solution were added to the solution prepared as stated above and the electrolysis continued until the mixture became alkaline, when the current was broken and the deposited metal washed, dried, and weighed in the usual manner. The solution became alkaline very quickly when electrolysed warm, but on an average about 25 per cent. of the total iron was deposited in this short period of fifteen to twenty minutes. Although alkaline, no separation of

ferric hydrate took place up to this stage, there being sufficient ammonium oxalate left to keep the iron salt in solution. In experiments 6 and 7 a larger proportion of oxalic acid solution (50 c.c.) was added to the original solution, which allowed the electrolysis to be continued for $1\frac{1}{2}$ hour before alkalinity was reached; the rate of deposition is evidently slowed by this increase of free acid. When cold solutions are electrolysed the deposition is quicker, as shown in experiments 8 and 9; the larger proportion of metal deposited is also partly due to the somewhat higher current and E.M.F. employed, and, taking this into account, the solution takes longer to get alkaline when electrolysed cold, as would be expected, since the rate of the decomposition of the oxalate will be slower. A comparison of experiments 5 and 8 with the remainder shows that, with less iron and the same proportion of oxalate, there is an increase in the proportion of iron deposited, despite the retarding effect of the

No.	Iron taken, gr.	Iron deposited, gr.	Per cent. Iron deposited	Time	Ammonium Oxalate Solution added, c.c.	Oxalic Acid Solution added, c.c.	C.D.$_{100}$ Ampere	E.M.F. Volts.	Temperature
1	0·0970	0·0415	42·8	14 min.	125	10	1·5	3·8	50°
2	0·0970	0·0300	30·9	11 ,,	125	10	1·5	3·8	50°
3	0·0970	0·0270	27·7	16 ,,	125	10	1·5	4·0	50°
4	0·0970	0·0230	23·7	17 ,,	125	10	1·6	3·9	50°
5	0·0194	0·0130	67·0	20 ,,	25	10	1·4	4·0	50°
6	0·0970	0·0410	42·3	$1\frac{1}{2}$ hr.	125	50	1·4–1·2	3·9–4·3	50°–56°
7	0·0970	0·0410	42·3	$1\frac{1}{2}$,,	125	50	1·4–1·1	3·9–4·5	50°–56°
8	0·0194	0 0160	82·5	25 min.	25	10	1·5	4·2	Cold
9	0·0970	0·0790	81·4	$1\frac{1}{2}$ hr.	125	50	1·5–1·8	4·7	Cold
10	0·0970	*a.* 0·0300	*a.* 30·9	$1\frac{1}{2}$,,	125	50	1·4–1·3	3·9–4·3	50°–53°
		b. 0·0630	*b.* 65·0	1 ,,					
		a + *b* 0·0930	95·9						
11	0·0970	*a.* 0·0410	*a.* 42·3	1h. 10m.	125	50	1·5–1·8	4·8	Cold
		b. 0·0520	*b.* 53·6	1 hr.					
		a + *b* 0·0930	95·9						

relative increase of free oxalic acid present. In experiments 10 and 11 the solutions were electrolysed till alkaline, and the deposited metal weighed (*a*); the solution was then poured back into the dish, and the electrolysis continued until a precipitate of ferric hydrate separated, when the additional iron deposited on the cathode was weighed (*b*). The deposition in both warm and cold solutions proceeds more rapidly after alkalinity than before, and there is evidently little difference in the results of the two experiments.

It is clear from these results that 5 gr. of ammonium oxalate will not outlast the deposition of 0·1 gr. of iron under the above conditions of current and E.M.F.; further, that an initial acidification with oxalic acid up to 4 gr. is no real help in preventing a separation of hydrate; and, finally, that it is advantageous to electrolyse cold solutions in preference to warm. To complete the deposition of iron under these circumstances it is necessary to add oxalic acid from time to time *during* the experiment, so as to prevent the separation of ferric hydrate; if this

is done, accurate results can be obtained, our own determinations, which need not be detailed here, confirming those of previous experimenters. The continuous attention thus entailed of course robs the method of its practical value.

Experiments were made on the use of *acid ammonium oxalate* instead of the neutral salt as the electrolyte, and it was found possible to complete the electrolysis without the addition of oxalic acid, 6 gr. of the acid salt being added to 0·1 gr. of iron as ferric chloride. But there is always a risk of ferrous oxalate separating out from this solution after the ferric salt has been reduced, which is extremely difficult to redissolve, so that the conditions of deposition were not regarded as worth further study.

By working with a lower current density and allowing the electrolysis to proceed for six hours, or preferably overnight, in cold solutions, it was found that 5 gr. of ammonium oxalate will outlast the deposition of 0·2 gr. of iron, and these conditions afford a thoroughly satisfactory method for the electrolytic determination of iron. The metal is deposited in a steel-grey, coherent form, and adheres equally well to a polished or sand-blasted dish; the washing and drying can be done without any fear of oxidation.

After some preliminary experiments it was found that a $C.D._{100}$ of 0·4 to 0·5 ampere and an E.M.F. of 3·0 to 3·5 volts are best; from five to six hours are necessary for the deposition of 0·1 gr. of iron. The following experiments illustrate the results to be obtained under these conditions; a ferric chloride solution was used, the excess of free acid being first neutralised as in Series I. Nos. 8–12 were consecutive experiments.

Series II.

No.	Iron taken, gr.	Iron deposited, gr.	Ammonium Oxalate Solution added, c.c.	$C.D._{100}$ Ampere	E.M.F. Volts	Time, Hours	Remarks
1	0·1060	0·1060	125	0·42–0·6	3·1–3·0	5	—
2	0·1060	0·1064	125	0·4 –0·6	3·2–3·0	6	—
3	0·1060	0·1066	125	0·4 –0·6	3·2–3·0	6	—
4	0·1060	0·1065	125	0·3 –0·29	2·8–2·9	—	Overnight
5	0·1060	0·1065	125	0·3 –0·29	3·2–3·2	—	,,
6	0·1060	0·1065	125	0·3 –0·2	3·2–3·6	—	,,
7	0·1060	0·1062	125	0·3 –0·2	3·2–3·6	—	,,
8	0·0920	0·0920	125	0·4 –0·32	2·3–2·6	17	,,
9	0·1840	0·1840	125	0·38–0·32	3·1–3·2	14½	,,
10	0·1050	0·1050	125	0·4 –0·36	2·0–2·5	18	,,
11	0·0920	0·0919	125	0·6 –0·55	3·0–3·5	18	,,
12	0·0920	0·0919	125	0·5 –0·5	2·8–2·8	18	,,

Note.—The two figures for Current and E.M.F. indicate the measurements at the beginning and end of the determinations respectively.

Considerable latitude is permissible in the current density and E.M.F., but it should be on the low side of the values given above. The determinations require no watching, and by allowing them to proceed overnight one of the most marked advantages of electrolytic analysis is gained.

Experiments made under similar conditions in warm solutions indicated no advantages whatever; the rate of deposition is not increased, and there is always a greater risk of ferric hydrate separating out, as already explained

2. *The Influence of Ammonium Chloride on the Electrolytic Determination of Iron.*

Since any iron solution in the ordinary course of analysis is likely to be acid with hydrochloric acid, a few experiments were made to decide whether the ammonium chloride formed by neutralising it has any deterrent effect on the deposition of the metal, since Classen states that it is desirable to remove free hydrochloric acid by evaporation previous to the electrolysis. 1 gr. of ammonium chloride was added to each of the solutions electrolysed under the conditions tabulated below; from the results it is evident that the addition is without influence on the determination of the iron.

Series III.

No.	Iron taken, gr.	Iron deposited, gr.	Ammonium Oxalate Solution added, c.c.	$C. D._{100}$ Ampere	E.M.F. Volts	Time, Hours
1	0·1060	0·1058	125	0·5–0·4	3·5–3·6	5
2	0·1060	0·1063	125	0·5–0·4	3·5–3·6	5

3. *The complete Separation of the Iron when deposited from Ammonium Oxalate Solution: the Sulphocyanide Reaction for Iron under the conditions of the Experiments.* By CHARLES A. KOHN, *M.Sc., Ph.D.*, F. J. BRISLEE, *and* H. H. FROYSELL.

The apparent accuracy of the results obtained in the electrolytic deposition of iron from ammonium oxalate solution has led the method to be regarded as free from the source of error generally associated with the deposition of metals from solutions of organic salts, viz. the separation of carbon with the metal at the cathode. Citrate and tartrate solutions both yield deposits containing a considerable proportion of carbon, and the quantitative results obtained are correspondingly high. Our own results with ammonium oxalate solution, contrary to those recorded in the literature on the subject, are hardly ever on the low side; they average from 0·2 to 0·3 per cent. high (Series II. p. 8). The possibility of compensating errors consisting in the presence of carbon with the deposited metal on the one hand, and the incomplete separation of the iron on the other, has recently been discussed by Avery and Dales [1] and by Verwer and Groll.[2] The former find that the deposited iron does contain carbon, on an average 0·21 to 0·42 per cent. on the metal deposited, and that some iron remains in the electrolysed solution. The latter was determined gravimetrically after evaporating the solution and igniting the residue, and in the three experiments made averages 0·35 per cent. The results published from the Aachen laboratory, on the other hand, confirm Classen's original view, that there is no carbon with the deposited iron, and that the iron is completely precipitated. Eight experiments are given by Verwer and Groll; the results are all low, a total of 7·6 mgr. of iron being wanting in the eight experiments. Still, no iron could be detected on evaporating all the solutions left after the electrolysis together, and testing with potassium sulphocyanide or other reagent after ignition and solution. These experiments were conducted with warm solutions, with a $C. D._{100}$

[1] *Ber.* 1899, **32**, 64 and 2233.

[2] *Ber.* 1899, **32**, 806.

=1·0 ampere, an E.M.F. of 2·5 to 3·0 volts, and the addition of 8 gr. of ammonium oxalate for 0·1 to 0·3 gr. of iron. From the contradictory nature of these results it became important to ascertain whether the accuracy of our own determinations was really due to small compensating errors.

To test the complete deposition of the iron in the experiments in Series II. (p. 178) a small quantity of the solution was withdrawn by a capillary tube, and tested with potassium sulphocyanide after acidifying with hydrochloric acid. The reaction is, however, known to be inhibited by the presence of organic acids, such as oxalic, unless a large excess of hydrochloric acid is present to prevent the dissociation of the ferric sulphocyanide; this addition may so far dilute the solution as to prevent the detection of small quantities of iron. Further, the metal is present as a ferrous salt at the end of the electrolysis, and this fact may also be a cause of any iron present escaping detection. The delicacy of the sulphocyanide reaction was, therefore, carefully studied under the conditions of the electrolytic experiments, as well as in presence of ammonium oxalate and of oxalic acid. Our results show that whilst up to 0·4 mgr. of iron can readily escape detection when the test is made by the usual method of withdrawing only a little of the solution, 0·1 mgr. can always be detected with certainty if the whole of the solution, after electrolysis, is tested by acidifying with 75 c.c. of hydrochloric acid (conc.), and then adding 10 c.c. of a 20 per cent. solution of potassium sulphocyanide. The coloration is quite distinct in presence of ammonium oxalate, oxalic acid, ammonium chloride, or of the salts remaining after the electrolysis of the mixture of these salts as used in the deposition of iron under the conditions of the experiments in Series II. The sequence of the addition of the reagents in no way affects the delicacy of the reaction, nor is the addition of any oxidising agent, such as hydrogen peroxide, necessary to convert the ferrous into ferric iron when solutions containing oxalic acid or its salts, or the products of their electrolysis, are tested; in their presence a little stirring appears ample to completely oxidise small quantities of iron. As a matter of fact, less than 0·1 mgr. can be detected thus, but this limit is of course sufficient to check the presence of iron left in the solution after electrolysis. With this check on the complete deposition of the metal a series of determinations were made, in which the iron remaining in solution was determined colorimetrically by potassium sulphocyanide after the electrolysis.

Series IV.

No.	Iron taken, gr.	Iron deposited, gr.	$C.D._{100}$ Ampere	E.M.F. Volts	Time, Hours	Iron left in solution, mgr.
1	0·1036	0·1036	0·5–0·42	3·4–3·7	23	0·1
2	0·1558	0·1560	0·5–0·45	2·3–3·0	23	0·2
3	0·2590	0·2592	0·5–0·46	3·1–3·7	23	0·3

The above were three consecutive experiments made with a ferric chloride solution prepared for electrolysis as in the previous experiments, and to which 5 gr. of ammonium oxalate were added. Despite the prolonged time of electrolysis a little iron still remained in solution; other

results showed the presence of 0·2 to 0·3 mgr. of iron in the electrolysed solution. Nevertheless, as in the experiments of Series II., the error in the weight of iron deposited is on the plus side.

4. *The Presence of Carbon in Iron deposited from Ammonium Oxalate Solution, and the Determination of its Amount.* *By* CHARLES A. KOHN, *M.Sc., Ph.D., and* F. J. BRISLEE.

To ascertain the presence of carbon in the metal deposited under the above conditions the following method was adopted :—A solution of ferric chloride, neutralised with ammonium hydrate, and to which ammonium oxalate was added, was electrolysed under the usual conditions, a piece of platinum foil being employed as the cathode. After the electrolysis the foil was thoroughly washed, then dried, and rolled up for combustion. The combustion was carried out in an ordinary combustion tube in a current of oxygen, a solution of barium hydrate being used for the absorption of the carbon dioxide. In every case a blank experiment was conducted for one hour before the introduction of the deposited iron, and the absorption bulbs weighed both at the beginning and end of the blank experiment; no difficulty, however, was found in keeping out all traces of carbon dioxide. The results tabulated below leave no doubt as to the presence of carbon in the deposited metal; the quantity appears to be independent of the quantity of iron precipitated, but increases with the quantity of ammonium oxalate in the solution electrolysed, when this is completely decomposed. The results are likely to err on the low side, as the combustion of the carbon deposited with the iron is likely to be incomplete. In order to make sure that the carbon dioxide was not derived from any slight residues that might have adhered to the iron from the alcohol used in the washing of the deposit, this washing was omitted in experiments 3 and 4, and the precipitated metal dried *in vacuo* after washing with water. Further, in experiment 4 the deposited iron, which was beautifully crystalline, was detached as far as possible from the platinum, and this portion (*a*) very completely washed with water before drying, so as to be certain that the carbon did not arise from any adhering traces of the decomposed oxalate solution; the iron that still remained on the platinum was combusted separately (*b*).

Series V.

No.	Iron deposited, gr.	Carbon found, mgr.	Per cent. Carbon on Iron deposited	Ammonium Oxalate added	Time, Hours	$C.D._{100}$ Ampere	E.M.F. Volts	Remarks
1	0·0814	0·60	0·74	6 gr.	19	0·4	5·2	Washed with water and alcohol
2	0·1908	0·82	0·43	6 gr.	$21\frac{1}{2}$	0·2	5·5	
3	0·1220	0·76	0·62	6 gr.	19	0·2	3·0	Washed with water and dried *in vacuo*
4	*a.* 0·0674	0·55	0·82	12 gr.	48	0·2	3·1	
	b. 0·2556	1·47	0·57					
	a + *b* 0·3230	2·02	0·62					

The variations in current density and electromotive force do not seem to make any appreciable difference. On an average the iron deposited from a solution containing 6 gr. of ammonium oxalate contains 0·84 mgr. of carbon, and, therefore, proportionately the results recorded in Series II.

and IV., in which 5 gr. of ammonium oxalate were used, should be 0·7 mgr. too high from this source of error. In the two sets of experiments the values obtained average an excess of 0·2 mgr., and the weight of metal remaining in solution after the determination is 0·2 to 0·3 mgr. These compensating errors, therefore, contribute to the apparent accuracy of the method ; they are sufficiently small to bring the process within the range of practical analysis. This conclusion is in accord with the experiments recorded by Avery and Dales ; the difference in the percentage of carbon found is in all probability due to the time of electrolysis. It is impossible to reconcile these results with those of Verwer and Groll ; but that their results, like those obtained by Classen, are low is undoubtedly to be attributed to the method adopted for testing the completion of the deposition of iron by means of potassium sulphocyanide. The origin and direction of the errors arising in the electrolysis of ammonium oxalate solutions containing iron are clearly shown by our experiments, and it is unlikely that different conditions prevail when other metals are present in the same electrolyte. The facts thus established must be duly considered in judging of the results obtained by these methods, especially in such cases as atomic weight determinations.

The quantities of carbon deposited with the iron were too small to allow of the investigation of its condition of combination. We are, however, inclined to think that it is present as a carbide, for whenever the deposited metal is dissolved in acid the smell of hydrocarbons can always be noticed ; also, after the upper layer of the metal has dissolved, the underlying portion is very often darker in colour and more difficult to dissolve.

5. *The Electrolytic Separation of Iron and Manganese in Ammonium Oxalate Solution.* *By* CHARLES A. KOHN, *M.Sc., Ph.D., and* H. H. FROYSELL.

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Classen, A., and Reis, M. A.	Ber.	1881	14	1,622	Ammonium oxalate
Classen, A.	,,	1881	14	2,771	Ammonium and potassium oxalates
,,	,,	1884	17	2,351	Ammonium and potassium oxalates
,,	,,	1885	18	168	Ammonium and potassium oxalates
,,	,,	1885	18	1,789	Ammonium oxalate
Engels, C.	Zeits. Electrochem.	1896	2	414	Ammonium acetate
,,	Chem. Rundschau	1896	—	5 and 20	Sulphuric acid
Kaeppel, F.	Zeits. anorg. Chem.	1898	16	268	Sodium pyrophosphate and phosphoric acid
Moore, T.	Chem. News	1886	53	209	Phosphoric acid and ammonium carbonate
Wieland, J.	Ber.	1884	17	2,931	Ammonium and potassium oxalates

In the electrolysis of manganese salts in presence of dilute mineral acids, sodium pyrophosphate, or ammonium oxalate, the manganese is separated at the anode as hydrated peroxide. This property is of little value, however, for the determination of manganese itself, because it is difficult to effect the complete separation of the metal as oxide, and special conditions must be adopted to cause the precipitate to adhere to the anode. On the other hand, the difference in the behaviour of iron and manganese when subjected to electrolysis in ammonium oxalate solution is attractive as a method for the separation of the two metals.

The practical difficulty in effecting a separation on these lines is that the precipitated manganic oxide always carries down some iron with it; this can only be overcome by adopting such conditions of electrolysis that only one of the metals is separated, the other remaining in solution. By means of a divided cell Engels states that manganese can be completely separated as peroxide, using a sulphuric acid solution; this involves the subsequent determination of the iron. The chief work on the subject, however, has aimed at the determination of the iron by deposition on the cathode, obviously the more useful line of separation.

According to Classen, the separation is possible if 8 to 10 gr. of ammonium oxalate are added to the solution of the mixed salts and the mixture electrolysed warm with a $C.D._{100}$ of about 1·0 ampere. This proportion of oxalate is said to outlast the deposition of the iron; the manganic oxide does not separate until the mass of the oxalate has been decomposed, and even with large proportions of manganese only very little peroxide separates at the anode under these conditions.

Neumann[1] and Engels[2] both state that the separation is incomplete, and our own experiments confirm this view. We have not found it possible to completely deposit iron without a separation of manganese peroxide, nor to separate the latter free from iron. The presence of even small proportions of manganese has, moreover, quite a remarkable effect in hastening the separation of iron as hydrate in the electrolysis of oxalate solutions. In some early experiments on the determination of iron the results were from 3 to 4 per cent. too low, and a separation of hydrate always took place after about two hours; on testing the precipitate it was found to contain manganese, derived from the iron wire used in making up the solution. In the subsequent work recorded above the iron was always purified from manganese by precipitation as basic acetate.

The following experiments show the extent of the error when the separation is conducted under the conditions most favourable for the deposition of the iron. The mixed chlorides of the two metals were neutralised with ammonium hydrate, 5 gr. of ammonium oxalate added, and electrolysed as usual. In experiments 4, 5, and 6, a $C.D._{100}$ of only 0·2 ampere was used; but still the deposition of the iron was incomplete, and in all cases manganese peroxide contaminated with iron separated at the anode or remained suspended in the solution. A comparison of the results tabulated on p. 184 shows that the error in the iron increases with the proportion of manganese taken.

[1] *Theorie u. Praxis der analytischen Electrolyse*, p. 194.
[2] *Chem. Rundschau*, 1896, pp. 5 and 20.

Series VI.

No.	Iron taken, gr.	Iron deposited, gr.	Manganese taken, gr.	Per cent. Iron deposited	$C.D._{100}$ Ampere	E.M.F. Volts	Time, Hours
1	0·1104	0·1080	0·0100	97·82	0·4–0·2	3–3·3	18
2	0·1104	0·1080	0·0250	97·82	0·4–0·3	3–3·8	18
3	0·1104	0·0964	0·1000	87·32	0·4–0·3	3–3·8	18
4	0·1104	0·1086	0·0100	98·37	0·2–0·16	3–3·1	18
5	0·1104	0·1070	0·0250	96·92	0·2–0·3	3–3·3	18
6	0·1104	0·1045	0·1000	94·65	0·2–0·3	3–3·4	18

Not more than 0·1 mgr. of iron was left in the solution as determined colorimetrically with sulphocyanide; the remainder must therefore have been carried down by the manganese peroxide; it was detected qualitatively in each case in the precipitate, but no quantitative estimations were made.

Direct experiments on the electrolysis of solutions of manganese chloride, to which 5 gr. of ammonium oxalate were added, and in which variations both of current and of electromotive force were tried, showed that it is not possible to electrolyse such solutions, under conditions permitting the deposition of iron, without the separation of manganese peroxide. The separation is effected the more rapidly the greater the proportion of manganese present and the higher the current density and the electromotive force. With only 0·01 gr. of manganese in solution, an E.M.F. of 3 volts, and $C.D._{100} = 0·2$ ampere, the precipitation of hydrate occurred after four hours' electrolysis in the cold solution, and in eighteen hours, the time required for an electrolytic determination of iron, with only 0·002 gr. of manganese, an E M.F. of 1·35 volts, and $C.D._{100} = 0·1$ ampere, the hydrate also separated. With the view of delaying this separation of the manganese a series of experiments were tried in which a small quantity of hydroxylamine sulphate was added to the solution to be electrolysed. It has been shown that this reagent acts favourably in preventing the separation of stannic acid in the electrolysis of tin salts in ammonium oxalate solution,[1] and it might, therefore, have a similar favourable effect in the case of manganese.

To a small extent this is the case; the addition of 1 gr. of hydroxylamine sulphate, under conditions similar to those recorded in Series II. of our experiments, considerably delays the separation of the hydrated peroxide. But the deposition of iron is also delayed, and attempts to separate the two metals with this addition gave results similar to those of Series VI. The separated peroxide contained iron, and the deposited metal was from 3 to 16 per cent. too low; in addition, the iron deposit was uneven and showed a tendency to scale off.

We therefore conclude that the quantitative separation of iron and manganese in ammonium oxalate solution cannot be effected. Further, the influence of small proportions of manganese on the electrolytic deposition of iron, referred to above, is a factor that detracts very considerably from the analytical value of the electrolytic method for the determination of the latter.

On the other hand, very small proportions of manganese can be sepa-

[1] Third Report, 1896.

rated qualitatively from iron or other metals, which are deposited at the cathode in the electrolysis of their solutions, with greater certainty than by the ordinary analytical methods.

6. *The Electrolytic Determination of Iron in Urine and other Animal Products. By* CHARLES A. KOHN, *M.Sc., Ph.D., and* G. C. CLAYTON, *Ph.D.*

Iron is the only heavy metal present in the body, and the part it plays in animal metabolism is of special interest. The varied conditions of its combinations can as yet only be approached by histochemical reactions; for its total and quantitative determination the ordinary volumetric, gravimetric, or colorimetric methods have been applied. As the quantities present in certain organs and excreta are extremely small, special importance attaches to the methods adopted for their estimation. The usual method of procedure is to dry and ignite the product to be tested, extract the residue with acid, and determine the iron in the resulting solution. In the case of urine, for instance, a day's discharge (about 1,500 c.c.) is evaporated and ignited until the residual ash is quite white, then dissolved in sulphuric acid and titrated with a dilute permanganate solution, after reduction with sulphurous acid (Hamburger [1]) or with zinc (Damaskin,[2] Jolles [3]). Gottlieb and Ludwig [4] employed a gravimetric method in which the iron is precipitated as Prussian blue in presence of a 1 per cent. zinc chloride solution, the precipitate subsequently decomposed by alkali, and the resulting ferric hydrate weighed after separation from the zinc by repeated precipitation with ammonium hydrate. More recently Jolles has recommended the gravimetric determination of iron in urine by precipitation with nitroso-β naphthol.[5] The great variations obtained by the adoption of these methods are shown in the following data as to the quantity of iron present in a day's discharge of normal urine:—

Hamburger	7·6 to 14·5 mgr. per 24 hours.
Gottlieb and Ludwig	1·59 to 3·69 ,,
Lieber and Mohr	0·8 to 1·7 ,,
Damaskin	0·5 to 1·5 ,,
Jolles	4·6 to 9·1 ,,
Kumberg	0·47 to 1·15 ,,

The values found by Damaskin, Lieber and Mohr, and Kumberg are usually regarded as the most correct, and 1 mgr. iron per diem in normal urine is looked upon as the average amount.[6]

Two sources of error beset these methods of analysis. In the first place, the very large quantity of mineral salts, especially chlorides and phosphates, left after ignition has a disturbing influence on the titration with permanganate, especially with such small proportions of iron as 1 mgr. in the total solution; secondly, it is impossible to completely remove the organic matter in the ignition, and its presence in solution affects the titration to a marked extent. These errors, which are of necessity irregular in character, are still more serious when gravimetric

[1] Kobert, *Pharmak. Mitteil.*, 1891, 7, 40.

[2] *Arbeiten d. pharmakolog. Inst.*, Dorpat, 1871, and *Zeits. anal. Chem.*, 1892, **31**, 481.

[3] *Zeits. anal. Chem.*, 1897, **36**, 149.

[4] *Archiv f. expt. Pathologie*, 1889, **27**, 139.

[5] *Loc. cit.*

[6] Stockman, *Brit. Med. Journ.*, 1893.

methods are adopted, whilst they make colorimetric methods altogether unreliable.

The electrolytic determination of iron presents the important advantage over the above by not being affected by these adverse conditions, and our results justify the conclusion that it is reliable and accurate. The presence of phosphoric acid does not interfere with the determination. Any organic matter present in the solution of the ash can be completely removed by a preliminary electrolysis in presence of sulphuric acid. This was proved in a series of experiments in which the attempt was made to effect the deposition of the metal directly in urine without concentration and ignition of the resulting ash. In order to overcome the frothing due to the decomposition of the urea in the urine, during the electrolysis, the latter was first decomposed with nitrous acid, the details of the method of determination being as follows : 100 c.c. of urine are treated in a flask with 12 c.c. of sulphuric acid (1 : 5) and 5 gr. of sodium nitrite, and gently warmed. After the decomposition is complete 5 c.c. of sulphuric acid (conc.) are added, the solution boiled to complete the decomposition of the urea, and electrolysed overnight with a $C.D._{100}=1{\cdot}0$ ampere. The urine is completely decolorised by the current, a crystal clear solution resulting, whilst a deposit of carbon quite free from iron takes place on the cathode. The solution is then neutralised with ammonium hydrate, oxalic acid added to acid reaction, then 5 gr. of ammonium oxalate, and boiled. The precipitated calcium oxalate, which does not retain any of the iron, is filtered off, washed, and the filtrate electrolysed either at 60°C. with a $C.D._{100}=1{\cdot}0$ to 1·5 ampere, or, better, overnight, cold, with a $C.D._{100}$ of 0·5 ampere and 3·0–4·0 volts. It is important not to decrease the proportion of oxalate, or magnesium carbonate may be formed on the cathode ; it is easily soluble in ammonium oxalate. A platinum spiral of 1 to 5 gr. weight, according to the quantity of iron present, is used as the cathode, and a platinum dish of about 200 c.c. capacity as the anode. The deposited metal, which is quite bright and metallic in appearance, after being washed, dried, and weighed, can be dissolved off, and the spiral re-weighed as a check on the determination, whilst confirmatory qualitative tests can, of course, be made with the resulting solution. In the following experiments known weights of iron were added to 100 c.c. of normal urine. (The quantity of metal present in the urine is negligible, less than 0·1 mgr.) A blank experiment was first made, with all the reagents employed in the method as described, to determine the contained iron and to make allowance for the carbon deposited ; the total amounted to 0·2 mgr., which was deducted in all cases.

Iron taken. gr.	Iron found. gr.	Iron taken. gr.	Iron found. gr.
0·0151	0·0152	0·0030	0·0027
0·0101	0·0100	0·0020	0·0015
0·0050	0·0051	0·0010	0·0008

The results show that 1 mgr. of iron per 100 c.c. of urine can be very satisfactorily estimated by this method ; but this amount is far in excess of that ever found in normal urine or likely to be present, even under pathogenic conditions. In both cases at least 1,000 to 1,500 c.c. should be used for a determination, and this when concentrated to, say, 200 c.c., is so highly charged with organic matter that even when electrolysed for

forty-eight hours in presence of sulphuric or nitric acid the decolorisation is incomplete. This direct method of determination is therefore inapplicable. The results are recorded to prove that the salts and organic matter are practically without influence on the deposition of the iron. The only alternative, therefore, is to evaporate to dryness, ignite, best after a preliminary drying at 180° C., and then proceed as above, omitting, of course, the decomposition with nitrous acid. Thus modified the method loses much of its absolute, but none of its relative value. A mixture of equal volumes of sulphuric acid (1 : 2) and hydrochloric acid (conc.) is best for the extraction ; the solution is then concentrated to remove hydrochloric acid, and electrolysed to destroy all traces of organic matter ; it is then ready for treatment with ammonium oxalate and the final electrolysis as described.

The following results with normal urine were obtained by this method :—

Volume of urine taken. c.c.	Iron found. m. gr.
3,750	1·9
1,320	1·1
1,020	0·9
1,600	0·9

Taking a day's discharge at 1,500 c.c., the average amount of iron per diem in the above experiments is 0·91 mgr., a value which confirms the most reliable of the results given above.

In all cases in which the determination of very small quantities of iron in organic products is concerned, the exceptional delicacy of the electrolytic method, its freedom from the sources of error that arise with other methods on account of the inherent presence of salts and of organic matter, and, finally, the ready check on the nature and amount of the deposited metal, render it capable of giving reliable and comparable results under all conditions. We have made use of it, with advantage, not only in the analysis of urine, but also in the determination of iron in liver, spleen, and fæces, both under normal and pathogenic conditions.

The Teaching of Science in Elementary Schools.—Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Lord AVEBURY, Professor W. R. DUNSTAN, Mr. GEORGE GLADSTONE, Sir PHILIP MAGNUS, Sir H. E. ROSCOE, Professor A. SMITHELLS, *and* Professor S. P. THOMPSON.

IT has been the custom of your Committee to give some comparative tables derived from the return of the Education Department showing the relative attention given to the teaching of scientific subjects in elementary schools for a period of years. By these it has been shown that for the eight years prior to 1890, during which time English Grammar was an obligatory subject provided any class subject was taken in the school, and as the Code allowed only two class subjects to be taken for the purpose of a grant, it was only in those schools where two of these were taken that

science teaching could be given throughout the standards. But the effect of this was that as the other recognised class subjects were History, Geography, and Elementary Science, and of these Geography was by far the most popular amongst the teachers, while English History was adopted in most other cases, Elementary Science scarcely received any attention at all. It should be borne in mind, moreover, that up to that date Geography itself was but little taught from a scientific standpoint, the details of topography occupying the pupils' time almost to the exclusion of the study of the physics of our globe. In the year 1889–90 the number of school departments in which English Grammar was taken amounted to no less than 20,304, while Elementary Science was taught in only 32. Since that year a free choice of subjects has been allowed, and the wide discrepancy between these figures has been regularly reduced year by year; in 1890–91 English dropped to 19,825, while Elementary Science rose to 173; and the table below will show the change that has been going forward since that date. It will be observed that Object Lessons were introduced in 1895, and these were made obligatory in the three lower standards on and after September 1, 1896. In the report presented by this Committee last year it was pointed out that the distinction between Object Lessons and Elementary Science was one of nomenclature rather than anything else, and now in the Government return for 1898–99 the distinction in name has been abolished, and all are included under the term Elementary Science.

Class Subjects—Departments	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98	1898–99
English . . .	18,175	17,394	17,032	16,280	15,327	14,286	13,456	13,194
Geography . .	13,485	14,256	15,250	15,702	16,171	16,646	17,049	17,872
Elementary Science	788	1,073	1,215	1,712	2,237	2,617	2,143	21,301
Object Lessons .	—	—	—	—	1,079	8,321	21,882	

The number of departments in 'schools for older scholars' for the year 1898–99 was 23,191, all but two of which took one or more class subjects. But History was taken in 5,879 departments, and needlework (as a class subject for girls) in 6,952 departments, and sundry minor subjects in 1,034, making, with the other three subjects of the table, a total of 66,232. This shows an average of nearly three class subjects to each department; but it must be borne in mind that the same subject is not always taken in all the standards, in which case three or more class subjects will appear in the return for a single department. That there has been less splitting up of the subjects between the upper and lower standards is apparent; and also that such a subject as Geography must, in some cases, have been taught by means of object lessons, as otherwise it would have been found by this time that the figure for object lessons had equalled the number of departments, whereas the 21,301 is actually considerably less than that for the previous year. It can hardly be assumed that under the regulations of the Code there was any actual diminution of such teaching.

It has been previously remarked that 'the increased teaching of scientific specific subjects in the higher standards is the natural consequence of the greater attention paid to natural science in the lower part of the schools.' The following table shows that such is the actual result:—

Specific Subjects: Children	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98	1898–99
Algebra . .	28,542	31,487	33,612	38,237	41,846	47,225	53,081	111,486
Euclid . .	927	1,279	1,399	1,468	1,584	2,059	2,471	5,932
Mensuration .	2,802	3,762	4,018	5,614	6,859	8,619	10,828	24,848
Mechanics .	18,000	20,023	21,532	23,806	24,956	26,110	27,009	50,324
Animal Physiology	13,622	14,060	15,271	17,003	18,284	19,989	22,877	41,244
Botany . .	1,845	1,968	2,052	2,483	2,996	3,377	4,031	8,833
Principles of Agriculture	1,085	909	1,231	1,196	1,059	825	870	1,163
Chemistry .	1,935	2,387	3,043	3,850	4,822	5,545	6,978	14,737
Sound, Light, and Heat	1,163	1,168	1,175	914	937	1,040	1,155	1,943
Magnetism & Electricity	2,338	2,181	3,040	3,198	3,168	3,431	3,905	7,697
Domestic Economy	26,447	29,210	32,922	36,239	39,794	45,869	51,259	95,171
Total .	98,706	108,434	119,295	134,008	146,305	164,089	184,464	363,378

It will be observed, however, that there is a very remarkable increase in the figures for 1898–99, and that this applies to every one of the specific subjects. Strictly speaking, the return for this year is not comparable with those for the previous years, as they represented the number of children who were presented for examination in these several subjects, whereas the return for this last year represents the number of scholars qualified for grants. In order to be so qualified in each subject, not less than twenty hours' instruction must have been received by each scholar, but calculating from the standard unit for estimating the grant, it would appear that the amount of time given during the year to such instruction was actually about fifty-two hours. The mean number of scholars in Standard V. and upwards was 716,157, which would give 50·7 per cent. as the proportion of scholars qualified for grant as compared with the possible number of students; but it must be remembered that nearly one-third of them take two subjects, and are therefore counted twice over. Though, as indicated above, too much stress must not be laid upon these increased figures, it is quite evident that the abolition of individual examination in the specific subjects has been received with favour by school managers and teachers, with the result that much more attention is devoted to this branch of instruction, and, it is to be hoped, with much less cramming.

The Code which has been introduced this year will further carry out this principle by substituting one block grant for all the elementary, class, and specific subjects, so as to avoid the temptation to study what would bring in the most grant rather than what is most adapted to the circumstances of the individual school. At the same time, the Code requires that 'lessons, including object lessons, on Geography, History, and Common Things be taken as a rule in all schools,' and that one or more of the subjects of instruction hitherto known as 'specific subjects' is to be taken 'when the circumstances of the school, in the opinion of the Inspector, make it desirable.'

For the guidance of teachers in preparing their course of study, the Board of Education (which now takes the place of the Education Department) have issued a number of specimen schemes adapted for

schools of different sizes and circumstances; and in the explanatory memorandum one of their objects is declared to be 'to make the course of instruction in all schools more comprehensive, so as to give all scholars the rudiments of general information, while enabling the details of the instruction to be adapted to the special needs of various kinds of schools.' It is added that in all schools both boys and girls 'should learn something of their own country, and be taught to observe and to acquire for themselves some knowledge of the facts of nature. . . . In country schools lessons on the objects and work of country life are valuable that would be inappropriate in town schools, while in the latter the instruction given in lessons on Common Things and in Elementary Science should be varied with reference to the probable future occupations of the children. . . . The introduction of a wider and more generally interesting course of instruction will, it is hoped, be a welcome relief from the continued repetition of the restricted course of lessons, which has a tendency to become lifeless and wearisome.' As an illustration may be quoted Scheme 5, for a boys' school in a seaside town, in which the course for 'Elementary Science and Common Things' is thus set out :—'Class V. to III. : A course of lessons on marine animals and plants, on local rocks, pebbles, &c.; various sorts of boats, ships, &c.; lighthouses and lightships; the local tides; flags of different nations, &c. Class II. : The magnet and compass; practical methods of finding the cardinal points; apparent movements of sun and moon; measurement of sun's altitude by shadows. Class I. : Practical measurements of areas and volumes; lever; pulley; inclined plane; practical examples of parallelogram of forces and parallelogram of velocities; the chief constellations and the apparent movements of heavenly bodies.'

Since the issue of the Code for this year the Board of Education have issued a minute establishing Higher Elementary schools. Higher-grade schools, as they have usually been called, have grown up in all the large industrial centres during the last twenty years or so, with the approval of the Education Department, though questions have been raised as to the right of School Boards to carry them on. All such doubts would be set aside by working under the minute, which provides for a four-year course, commencing at a point equivalent to Standard V., and contemplating a continuance of study up to fifteen years of age. No definite scheme of instruction is laid down in the minute, as that is to be regulated by 'the circumstances of the scholars and the neighbourhood,' and the grants will be assessed at the higher or lower scale according to 'the thoroughness and intelligence with which the instruction is given, the sufficiency and suitability of the staff, the discipline and organisation.' Though there are some inconvenient restrictions which it may be found necessary to modify, the effect of this minute should be in the direction advocated by your Committee.

This, however, will depend absolutely upon the will of the Managers and the consent of the Board of Education, as the minute only provides that 'the Managers of any school who desire such school to be recognised as a Higher Elementary School must submit for the approval of the Board before July 1 in any year proposals for a curriculum and time table, and supply such other information as may be required by the Board.' In contrast to this may be quoted the provisions of the Scotch Code for Higher Grade Schools, which include the following :—'Such schools or departments may give an education which is either predominantly

scientific and technical—Higher Grade (Science) Schools—or predominantly commercial—Higher Grade (Commercial) Schools, or they may give a course which is recognised by the Department as specially suited to girls or to special classes of pupils. In all cases the Department must be satisfied that the school possesses the proper provision of class rooms, laboratories, and workshops necessary for the particular type of education to be given therein. . . . Pupils following the Higher Grade Science course must take in addition the following subjects: Mathematics, Experimental Science, and as a rule some form of Manual Work. . . . In the second year of the Higher Grade Science course not less than eight, and in the third year not less than ten, hours a week must, as a rule, be allotted to Science, and at least half of this time must be spent by the pupils in individual experimental work. For the purpose of this article three hours of Drawing or of Manual Instruction, or of both conjointly, will be reckoned as equivalent to two hours of Science. In the third and following years Manual Instruction may be dropped, and the pupil should devote himself to the study of some special branch of Science.' In Appendix V. it is further stated: 'The course in Science should proceed from elementary exercises in measuring and weighing, and calculations based thereon, to the experimental investigation of elementary notions of Physics and Chemistry. In rural schools, and in summer, some investigation of plant life and of the elements of Botany should be added. At least half the time devoted to this subject should be spent by each pupil in practical work. . . . The Department must be satisfied that the teachers have a competent knowledge of the subjects which they are to teach in each subject individually, and in the case of Science that they have had experience in treating the subject experimentally.'

In the Reports for 1897 and 1898 your Committee referred to the improvements which were being effected in the teaching of Science in the London Board Schools, and to Professor Fitzgerald's advocacy of the extension of the same system to Ireland. The Commission on Practical and Manual Instruction, of which he was a member, reported strongly in favour of such work, and decided that similar instruction should be given in schools under the National Board of Education. To this end Mr. Heller (whose transference from London to Birmingham has been already noted) has been appointed Organiser of Science Instruction in Irish Schools, and will take up his new duties as soon as he can be released from the Headmastership of the Municipal Technical School of Birmingham. The syllabuses of specific subjects in the Irish Code are similar to those in the English Code of regulations. For the present a scheme corresponding to Course H of the English Code has been introduced in a slightly modified form, and notes have been added indicating the spirit in which the instruction should be given. A training laboratory is being equipped in Dublin at which selected teachers will be taken through a course of instruction in heuristic methods, and where they will receive the benefit of the experience gained in the London schools. The training colleges not under the control of the National Board are also understood to be sympathetic, so that there is very good prospect that the Science teaching in National Schools in Ireland will be energetically developed.

The advance which was noted last year in the work of the Evening Continuation Schools does not seem to have been maintained, as will be evident from the following table. Nearly all the subjects show a falling off, except Elementary Physics and Chemistry, Domestic Science and

Navigation, which give an increase; and Horticulture and Ambulance, which are practically stationary.

Science Subjects	Number of Scholars		
	1896–97	1897–98	1898–99
Euclid	1,036	1,525	1,216
Algebra	7,467	9,996	7,432
Mensuration	27,388	29,966	24,369
Elementary Physiography	3,712	4,807	4,213
Elementary Physics and Chemistry	3,135	2,902	3,116
Domestic Science	—	117	142
Science of Common Things	10,910	13,874	11,499
Chemistry	5,658	6,590	5,963
Mechanics	1,365	1,129	987
Sound, Light, and Heat	726	813	437
Magnetism and Electricity	3,834	3,967	3,005
Human Physiology	5,865	6,237	4,296
Hygiene	3,179	4,062	3,276
Botany	692	763	597
Agriculture	2,355	2,300	1,826
Horticulture	1,001	1,354	1,350
Navigation	68	37	46
Ambulance	9,086	13,030	12,980
Domestic Economy	19,565	23,271	19,915
Totals	107,042	126,740	106,665

In the last Report reference was made to the increased attention which was being given by the School Board for London to the teaching of Experimental Science in their schools, and to the preparation of a properly qualified staff of teachers for that work. In this they have had the advantage of the advice of Dr. C. W. Kimmins. The supply of suitable accommodation and appliances for carrying this out has also been seen to, so that the Board have at the present time more or less complete provision for the experimental teaching of science in 79 of their schools: of these 11 are pupil-teacher centres, 37 are classed as higher-grade schools, and 31 as ordinary schools. In some cases there are both chemical and physical laboratories, with lecture rooms furnished with demonstration tables, with gas and water laid on; in others there is only one laboratory specially fitted for Chemistry, but which can also be made available for the teaching of Physics.

In the Act of Parliament creating the Board of Education it was provided that a Consultative Committee should be established, two-thirds of the members of which should consist of 'persons qualified to represent the views of Universities and other bodies interested in Education;' and it will be noted with satisfaction that one of the members of your Committee—Professor Henry E. Armstrong—has been nominated to that office.

On Wave-length Tables of the Spectra of the Elements and Compounds. —*Report of the Committee, consisting of* Sir H. E. ROSCOE (*Chairman*), Dr. MARSHALL WATTS (*Secretary*), Sir J. N. LOCKYER, Professor J. DEWAR, Professor G. D. LIVEING, Professor A. SCHUSTER, Professor W. N. HARTLEY, Professor WOLCOTT GIBBS, *and* Captain ABNEY.

Index to the Tables of Wave-lengths in the Reports of the British Association from 1884 *to* 1900.

Abbreviations: Sp. = Spark Spectrum; A. = Arc Spectrum; Ab. = Absorption Spectrum; Fl. = Flame Spectrum; Bd. = Band Spectrum; L. = Line Spectrum; Cl. = Compound-line Spectrum; V. = Vacuum-tube Spectrum; P. = Phosphorescent Spectrum.

Strontium Chloride, 1866, p. 168; 1894, p. 258.
Bromide, 1866, p. 168.
Fluoride, 1866, p. 168.
Iodide, 1866, p. 168.
Oxide, Fl., 1866, p. 169; 1894, p. 258; 1895, p. 321.
Sulphur, L., 1880, p. 272; 1885, p. 290.
Bd., 1880, p. 272; 1885, p. 290.

TANTALUM, A., 1885, p. 292.
Tellurium, L., 1880, p. 273; 1885, p. 292.
Bd., 1885, p. 292.
Fl., 1895, p. 323.
Terbium, Sp., 1885, p. 296.
Thallium, Fl., 1885, p. 297.
Sp., 1885, p. 297.
A., 1885, p. 297; 1893, p. 403.
Thorium, Sp. 1885, p. 298.
Thulium, Sp., 1885, p. 298.
Tin, Fl., 1895, p. 327.
Sp., 1885, p. 299.
A., 1885, p. 299.
Tin Oxide, 1866, p. 169.

Titanium, Sp., 1885, p. 301.
A., 1885, p. 301; 1896, p. 293.
Tungsten, Sp., 1885, p. 304; 1898, p. 355.

URANIUM Sp., 1885, p. 304; 1900, p. 201.

VANADIUM, Sp., 1885, p. 304.

WATER, A., 1866, p. 169.
Ab., 1886, p. 171; 1891, p 245.

YTTERBIUM, Sp., 1885, p. 305.
Yttrium, Sp., 1885, p. 306.
A., 1885, p. 306.
Yttrium Oxide, P., 1886, p. 186.

ZINC, Sp., 1885, p. 307.
A., 1885, p. 307; 1892, p. 207.
Zirconium, Sp., 1885, p. 309.
A., 1885, p. 309.

The Solar Spectrum, 1878, p. 37; 1895, p. 273.
Telluric Lines of the Solar Spectrum, 1886, p. 171; 1891, p. 245.
Bibliography of Spectroscopy, 1881, p. 328; 1884, p. 295; 1894, p. 161; 1898, p. 439.
Spectra of Metalloids, 1880, p. 258.
On the Influence of Temperature and Pressure on Spectra, 1880, p. 275.
Absorption Spectra of Rays of High Refrangibility, 1880, p. 303.
General Methods of Observing and Mapping Spectra, 1881, p. 317.
Genesis of Spectra, 1882, p. 120.
Ultra Violet Spark Spectra, 1882, p. 143; 1883, p. 127; 1885, p. 276.

BROMINE (VACUUM-TUBE).

Eder and Valenta, 'Denkschr. kais. Akad. Wissensch. Wien,' Bd. lxviii. 1899.

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
		Salet	Plücker and Hittorf	$\lambda+$	$\frac{1}{\lambda}-$	
6682·83	2	6990	6862	1·81	4·0	14959·7
32·02	5	6631	6622	1·80	4·1	15074·3
6582·52	1	6581	6577	1·79	,,	187·6
60·17	4	6556	6556	1·78	,,	239·4
45·00	½			,,	,,	274·7
6353·07	1			1·73	4·3	736·1
51·02	10	6357	6358	,,	,,	741·2
6204·36	½			1·69	4·4	16113·3
6178·72	2			1·68	,,	180·2
70·09	2			,,	,,	202·8
59·60	2			,,	,,	230·4
49·95	10	6166	6159	1·67	,,	255·9
42·02	4		6152	,,	,,	276·9
23·49	3		6132	,,	,,	326·2
18·89	4		6129	,,	,,	338·4
6097·05	1			1·66	,,	397·0

BROMINE (VACUUM-TUBE)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
		Salet	Plücker and Hittorf	λ+	$\frac{1}{\lambda}$−	
5954·3	½			1·62	4·6	16790
50·7	½			,,	,,	800
40·83	4			,,	,,	828·1
5871·97	3	5881		1·60	,,	17025·5
68·40	2		5869	,,	,,	032·3
64·55	3			,,	,,	047·0
52·40	5			1·59	,,	082·4
33·71	3			,,	4·7	17137 2
31·04	7	5841	5828	,,	,,	144·9
21·40	3		5825	,,	,,	173·3
5794·50	2		5793	1·58	,,	17253·0
—	—		5740	—	—	—
19·17	4	5721	5723	1·56	4·8	17480·3
16·5	½			,,	,,	488
11·25	4		5713	,,	,,	17504·5
—	—		5697	—	—	—
5657·83	4		5663	1·54	,,	17669·8
43·40	½			,,	,,	17715·0
30·3	1			,,	,,	756
27·5	1b		5627	1·53	,,	765
22·38 }	1		5623	,,	,,	781·3
21·95 }	1			,,	,,	782·6
5600·90	4	5601	5599	,,	4·9	17849·4
5590·15	8			1·52	,,	883·7
88·40	2			,,	,,	889·3
84·98	1			,,	,,	900·3
60·10	1		5567	,,	,,	980·4
45·91	1		5553	1·51	,,	18026·4
39·21	1			,,	,,	048·2
36·52	4			,,	,,	057·0
32·38	½			,,	,,	070·5
29·19	2			,,	,,	080·9
16·87	1	5516	5516	,,	,,	18121·3
11·04	2			1·50	,,	140·5
08·49	3			,,	,,	148·9
06·97	8			,,	,,	153·9
5495·24	7	5501	5503	,,	5·0	192·6
89·00	6	5496	5493	,,	,,	18213·2
83·20	2			,,	,,	232·5
81·41	2			,,	,,	238·5
80·20	3b			,,	,,	242·5
66·43	5			1·49	,,	288·5
50·28	3	5451	5447	,,	,,	18342·7
42·55	4			,,	,,	368·7
35·30	5		5437	1·48	,,	393·2
33·49	1			,,	,,	399·4
25·21	5	5426	5429	,,	,,	18427·5
23·01	7		5423	,,	,,	434·9
5395·69	5		5392	1·47	5·1	18528·2
—	—		5384	,,	,,	—
70·51	2b▾			,,	,,	18615·1
64·38	3b▾			,,	,,	636·4
60·99	2			1·46	,,	648·2
45·53	4b▾			,,	,,	18702·1
35·30	5	5336	5327	,,	,,	738·0

BROMINE (VACUUM-TUBE)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
		Salet	Plücker and Hittorf	$\lambda +$	$\frac{1}{\lambda} -$	
5333·49	1			1·46	5·1	18744·4
32·18	10			”	”	749·0
30·76	2			”	”	754·0
04·31	7		5300	1·45	”	18847·5
—	—	5311	5293	”	”	—
5272·89	4	5276	5264	1·44	5·2	18963·3
63·68	4	5267	5251	”	”	992·9
49·219	3			1·43	”	19045·26
39·994	2	5241	5226	”	”	078·79
38·472	8			”	”	084·34
33·65	2		5221	”	”	102·9
27·911	3		5217	”	”	129·4
—	—			”	”	—
5199·50	3			”	5·3	227·3
94·075	4b			1·42	”	247·4
84·074	4		5188	”	”	284·5
82·573	7			”	”	290·1
80·19	2	5186	5181	”	”	299·0
74·09	1			1·41	”	321·8
64·560	5	5166	5169	”	”	361·2
43·626	2		5151	”	”	436·3
—	—		5123	1·40	”	—
—	—		5107	”	”	—
—	—		5093	1·39	”	—
5054·853	4	5061	5055	”	5·4	777·6
38·962	3b		5036	1·38	”	840·0
20·756	3			1·37	5·5	911·8
11·000	1		5011	”	”	950·6
02·96	1			”	”	982·7
4987·234	1		4991	1·36	”	20045·7
79·950	4s		4983	”	”	075·0
59·51	4b		4961	”	”	157·8
45·768	3n		4956	1·35	”	213·8
42·21	1n			”	5·6	228·3
30·816	5s	4931	4933	”	”	275·0
28·966	5s		4925	”	”	282·6
26·758	2n			”	”	291·8
21·386	3n			”	”	313·9
21·20	1n			”	”	314·6
4867·935	3b		4869	1·33	”	537·0
66·851	3b			”	”	541·5
48·988	6s		4853	”	5·7	617·2
45·196	3b		4848	”	”	633·3
38·823	3			1·32	”	660·5
34·699	2n			”	”	678·1
16·900	8s	4816	4819	”	”	754·5
02·544	4s		4808	1·31	”	816·6
4799·794	3n			”	”	828·5
98·415	3n			”	”	834·5
91·989	2n			”	”	862·5
85·644	10s	4786	4788	”	”	890·1
80·524	6s		4779	”	5·8	912·4
77·30	3s			”	”	926·5
76·605	7s			”	”	929·6
75·41	3s			”	”	934·8

BROMINE (VACUUM-TUBE)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
		Salet	Plücker and Hittorf	$\lambda +$	$\frac{1}{\lambda} -$	
4774.01	4s			1·31	5·8	20945·3
72·91	3b		4772	,,	,,	945·8
67·282	8s			1·30	,,	970·5
66·27	5b^v			,,	,,	975·0
53·05	1			,,	,,	21033·3
52·47	3b			,,	,,	035·9
50·10	2b			,,	,,	046·4
44·53	3b		4747	,,	,,	071·1
42·87	8s		4737	,,	,,	078·5
35·67	5b^v		4731	,,	,,	110·5
28·90	2			1·29	,,	140·8
28·49	4			,,	,,	142·6
20·56	1b^v	4721	4721	,,	,,	178·1
19·95	8			,,	,,	180·9
17·57	3b			,,	,,	191·5
14·66	1n			,,	,,	205·0
11·32	1			,,	,,	219·7
08·16	1			,,	,,	233·9
05·00	10b	4706	4707	,,	5·9	248·1
01·93	2n			,,	,,	262·0
4698·77	2n		4696	,,	,,	276·3
96·59	2n			,,	,,	286·1
93·48	8s			,,	,,	300·3
92·51	3b			1·28	,,	304·7
91·42	3b			,,	,,	309·6
78·89	8b	4676	4681	,,	,,	366·7
75·82	2s		4677	,,	,,	380·7
73·56	2s			,,	,,	391·1
72·750	6s			,,	,,	394·8
66·42	2			,,	,,	423·8
52·18	6s			1·27	,,	489·4
44·17	2n		4645	,,	,,	526·5
43·74	4s			,,	,,	528·4
42·35	3b			,,	,,	534·7
29·66	3b			,,	6·0	593·9
22·99	8s	4621	4626	,,	,,	630·4
14·86	6s			1·26	,,	662·6
05·90	2b			,,	,,	705·3
01·63	5n			,,	,,	725·4
4597·14	3n			,,	,,	746·7
75·95	6b^v			1·25	,,	847·4
58·21	4n			,,	6·1	932·3
43·12	8s	4543	4544	,,	,,	22005·2
42·67	2n			,,	,,	007·4
38·95	5b			,,	,,	025·4
30·21	1			,,	,,	067·9
30·00	5s			,,	,,	069·0
29·78	2s			,,	,,	070·0
25·82	8b^v			,,	,,	089·3
13·99	1			1·24	,,	147·2
13·67	5s			,,	,,	148·8
08·29	2n			,,	,,	175·3
4477·96	5b^v	4486		1·23	6 2	325·4
72·83	8			,,	,,	351·0
71·99	1			,,	,,	355·2

BROMINE (VACUUM-TUBE)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
		Salet	Plücker and Hittorf	$\lambda +$	$\frac{1}{\lambda} -$	
4470·22	1			1·23	6·2	22364·1
66·42	1n			1·22	,,	383·1
65·99	1n			,,	,,	385·2
60·92	1			,,	,,	410·7
60·39	1			,,	,,	413·4
53·75	1			,,	,,	446·8
41·94	8bv			,,	,,	506·5
31·13	2			,,	6·3	561·3
30·07	2			1·21	,,	566·7
25·32	5s			,,	,,	590·9
23·22	2			,,	,,	601·7
12·66	1			,,	,,	655·8
07·80	4			,,	,,	680·8
05·18	1			,,	,,	694·3
4399·87	3			,,	,,	721·6
96·55	5			,,	,,	738·8
95·10	4			,,	,,	746·3
91·76	3			1·20	,,	763·6
86·83	2n			,,	,,	789·2
78·11	4b			,,	,,	834·6
77·40	2s			,,	,,	838·3
72·20	3n			,,	,,	865·5
65·76	8s	4368	4366	,,	6·4	899·2
65·31	4s			,,	,,	901·5
4297·27	3s			,,	6·5	23264·1
91·54	6	4287	4288	1·18	,,	300·6
36·998	6s			,,	6·6	595·0
30·101	4	4231	4242	1·17	,,	633·4
23·996	8		4229	1·16	,,	667·7
02·64	4s		4199	1·15	,,	788·0
4193·62 }	6			,,	6·7	839·0
93·34 }	2			,,	,,	840·6
79·76	8	4181	4182	,,	,,	918·1
75·92	5s			,,	,,	940·1
75·77	1			,,	,,	941·0
60·14	2s			1·14	,,	24031·0
57·54	2			,,	,,	046·0
57·23	3s			,,	,,	047·8
51·52	3s			,,	,,	080·9
44·12	2s			,,	6·8	123·8
40·37	6s		4143	,,	,,	145·6
38·78	3b			,,	,,	155·9
35·79	5s			,,	,,	172·4
17·58	3b			1·13	,,	279·3
10·12	4			,,	,,	323·4
09·96	1			,,	,,	324·3
06·52 }	3s			,,	,,	344·7
05·56 }	2s			,,	,,	350·4
02·62	4			,,	,,	368·3
4096·27	3b			,,	6·9	405·6
90·74	3s			1·12	,,	438·5
89·29	3b	3981		,,	,,	447·2
75·66	4b			,,	,,	529·0
37·486	2s			1·11	7·0	760·9
36·538	4s			,,	,,	766·7

BROMINE (VACUUM-TUBE)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
		Salet	Plücker and Hittorf	$\lambda+$	$\frac{1}{\lambda}-$	
4024·19	5b^{v}			1·11	7·0	24842·7
22·04	2			,,	,,	856·0
21·95	1			,,	,,	856·6
12·70	3s			1·10	,,	913·9
08·93	6b^{v}			,,	,,	937·3
07·45	5s			,,	,,	946·5
05·69	2s			,,	,,	957·5
01·60	3b			,,	7·1	982·9
3999·77	4b			,,	,,	994·3
97·27	4b			,,	,,	25010·0
92·51	4s			,,	,,	039·8
91·485	3s			,,	,,	044·2
86·666	8s			,,	,,	076·5
80·585	10n			,,	,,	114·8
80·151	5s			,,	,,	117·6
68·804	5s			1·09	,,	189·4
55·504	8b^{v}			,,	7·2	274·6
50·745	7b^{v}			,,	,,	304·5
39·862	5b^{v}			,,	,,	374·4
38·801	5b^{v}			,,	,,	381·2
35·310	6b^{v}			1·08	,,	403·8
29·726	6b			,,	,,	440·9
24·239	8b^{v}			,,	,,	475·4
23·506	6			,,	,,	480·2
20·838	6b^{v}			,,	,,	497·5
19·770	6s			,,	,,	504·5
17·960	3s			,,	,,	516·3
14·419	9			,,	,,	539·4
14·270	—			,,	,,	540·3
01·418	4			,,	7·3	624·4
3891·790	8s			,,	,,	687·9
88·665	4b^{v}			1·07	,,	709·5
71·377	6s			,,	,,	823·3
57·363	6s			,,	,,	917·1
40·775	3b^{v}			1·06	,,	26029·1
34·861	6b^{v}			,,	,,	069·3
29·920	3n			,,	,,	102·9
28·640	3			,,	,,	111·5
15·771	4s			1·05	7·4	199·6
11·55	3			,,	,,	228·6
01·09	1s			,,	,,	300·8
3794·153	4s			,,	,,	349·0
72·727	4b			1·04	7·5	498·5
70·410	2b			,,	,,	514·8
53·87	4b			,,	,,	631·7
40·66	5b			,,	,,	725·7
37·82	2b			1·03	,,	746·1
35·91	1			,,	,,	759·7
25·54	1			,,	7·6	834·1
14·45	4			,,	,,	914·3
3699·595	2			1·02	,,	27022·4
84·84	3			,,	,,	130·6

URANIUM.

Exner and Haschek, 'Sitzber. kais. Akad. Wissensch. Wien,' cvii., 1898.

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
4699·95	1n	1·29	5·9	21270·9
99·3	1n	,,	,,	274
99·02	1n	,,	,,	275·1
97·55	1n	,,	,,	281·8
96·77	1	,,	,,	285·3
96·30	1	,,	,,	287·5
95·4	1b	,,	,,	292
93·95	1n	,,	,,	298·1
92·6	1b	1·28	,,	304
92·32	1n	,,	,,	305·5
92·15	1n	,,	,,	306·3
91·45	1n	,,	,,	309·5
90·95	1n	,,	,,	311·7
90·1	1b	,,	,,	312
89·27	3	,,	,,	319·4
88·0	1n	,,	,,	322
87·1	1n	,,	,,	329
85·9	2n	,,	,,	335
84·87	1n	,,	,,	339·4
84·20	1	,,	,,	342·5
83·85	1	,,	,,	344·0
83·29	1	,,	,,	347·0
82·90	1	,,	,,	348·4
82·77	1	,,	,,	349·0
82·33	1n	,,	,,	351·0
81·40	1n	,,	,,	355·1
80 85	1n	,,	,,	358·6
80·4	1n	,,	,,	360
78·8	1b	,,	,,	367
78·1	1b	,,	,,	370
75·6	1n	,,	,,	382·5
74·45	1n	,,	,,	386·9
74·0	1n	,,	,,	389
71·66	2	,,	,,	399·7
69·55	1	,,	,,	409·4
69·22	1	,,	,,	411·0
69·05	1	,,	,,	411·7
68·67	1	,,	,,	413·5
67·45	1	,,	,,	419·1
67·07	2	,,	,,	420·8
66·23	1	,,	,,	424·7
65·42	1	,,	,,	428·4
64·98	1	,,	,,	430·4
64·30	1	,,	,,	433·5
63·97	1	,,	,,	435·1
63·2	1b	,,	,,	439
62·78	1	,,	,,	440·6
62·40	1	,,	,,	442·3
61·87	1n	,,	,,	444·7
61·0	1n	,,	,,	449
60·1	1n	,,	,,	453
59·52	1n	,,	,,	455·5
58·92	1n	,,	,,	458·2

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4658·4	1b	1·28	5·9	21461
57·6	1b	,,	,,	464
56·7	1n	,,	,,	468·5
55·40	1n	,,	,,	474·5
55·03	2	,,	,,	475·7
54·43	1n	1·27	,,	478·9
53·65	1	,,	,,	482·6
53·25	1	,,	,,	484·4
53·05	1	,,	,,	485·4
52·09	1	,,	,,	489·7
51·75	1n	,,	,,	491·4
50·7	1n	,,	,,	496
50·24	1	,,	,,	498·2
49·37	2n	,,	,,	502·2
48·15	1	,,	,,	508·0
46·85	4	,,	,,	514·0
46·30	1	,,	,,	516·6
45·80	1n	,,	,,	518·9
45·13	1n	,,	,,	522·1
44·30	1	,,	,,	525·9
43·86	1	,,	,,	527·9
42·72	1n	,,	,,	533·2
41·91	2	,,	,,	536·9
40·57	1	,,	,,	543·0
39·3	1b	,,	,,	549·5
38·16	1n	,,	,,	554·7
35·73	1n	,,	,,	565·7
35·2	1n	,,	,,	568
34·2	1n	,,	,,	573
31·92	1	,,	,,	583·4
31·81	1	,,	,,	583·9
31·1	1b	,,	,,	587
30·4	1b	,,	,,	590
29·94	1	,,	6·0	592·6
29·37	1n	,,	,,	595·2
28·5	1b	,,	,,	599
27·30	5	,,	,,	605·0
26·14	1	,,	,,	610·4
25·26	1n	,,	,,	614·5
24·91	1n	,,	,,	616·1
24·27	1n	,,	,,	619·1
23·68	1	,,	,,	620·8
22·23	1	,,	,,	627·5
22·13	1	,,	,,	628·0
20·42	3r	,,	,,	636·9
19·4	1n	,,	,,	642
18·60	2d	,,	,,	645·7
17·80	1n	,,	,,	649·3
17·33	1n	,,	,,	651·5
16·7	1n	1·26	,,	654·5
15·85	1n	,,	,,	658·5
15·32	1n	,,	,,	661·0
15·18	1n	,,	,,	661·6
14·90	1	,,	,,	662·9
14·50	1n	,,	,,	664·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4612·8	1n	1·26	6·0	21673
12·47	1n	,,	,,	674·3
11·70	2	,,	,,	678·0
10·07	2n	,,	,,	685·7
09·0	1b	,,	,,	691
06·4	1n	,,	,,	703
05·38	3	,,	,,	707·7
03·88	4	,,	,,	714·8
02·04	1	,,	,,	723·5
01·38	2	,,	,,	726·6
00·96	1	,,	,,	728·6
00·13	1	,,	,,	732·5
4599·73	1n	,,	,,	734·4
99·03	1	,,	,,	737·7
98·51	1	,,	,,	740·2
98·05	1	,,	,,	742·4
97·77	1	,,	,,	743·7
96·95	1n	,,	,,	747·6
95·91	1n	,,	,,	752·5
95·73	1n	,,	,,	753·3
95·30	1	,,	,,	755·4
94·49	1	,,	,,	759·3
92·75	1n	,,	,,	767·4
91·96	1	,,	,,	771·2
91·0	1n	,,	,,	776
90·46	1n	,,	,,	778·2
90·21	1n	,,	,,	779·4
89·55	1n	,,	,,	782·5
88·6	1n	,,	,,	787
88·1	1n	,,	,,	789·5
87·45	1n	,,	,,	792·5
87·1	1n	,,	,,	794
86·5	1n	,,	,,	797
85·75	1n	,,	,,	800·6
85·03	2	,,	,,	804·0
84·5	1n	,,	,,	807
83·52	1	,,	,,	811·2
83·00	1	,,	,,	813·8
82·65	1n	,,	,,	815·5
81·98	2	,,	,,	818·7
81·33	1n	,,	,,	821·7
81·02	1n	,,	,,	823·2
79·87	1	1·25	,,	823·9
79·20	1	,,	,,	831·9
78·5	1b	,,	,,	835
77·40	1	,,	,,	840·5
76·85	1	,,	,,	843·1
76·25	1n	,,	,,	846·0
75·3	1b	,,	,,	850·5
75·00	1	,,	,,	851·9
74·6	1n	,,	,,	854
73·90	3d	,,	,,	857·2
73·50	1	,,	,,	859·1
73·2	1n	,,	,,	860·5
72·47	1n		,,	864·0

Uranium—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4571·8	1n	1·25	6·0	21867
71·50	1	,,	,,	868·6
71·16	1	,,	,,	870·2
70·87	1	,,	,,	871·6
70·11	3	,,	,,	875·2
69·40	1	,,	,,	878·7
68·41	1	,,	,,	883·4
67·89	3	,,	,,	885·9
67·1	1b	,,	,,	890
65·8	1b	,,	,,	896
64·50	1n	,,	6·1	902·1
64·26	1n	,,	,,	903·3
63·56	1n	,,	,,	906·7
62·10	1	,,	,,	913·6
61·6	1n	,,	,,	916
61·45	1n	,,	,,	916·7
60·50	1	,,	,,	921·8
60·0	1b	,,	,,	924
58·60	1	,,	,,	930·5
58·32	1	,,	,,	931·8
58·07	1	,,	,,	933·0
57·99	1	,,	,,	933·4
56·50	1	,,	,,	940·5
56·18	1	,,	,,	942·1
55·30	4	,,	,,	946·3
54·03	2	,,	,,	952·5
53·1	1n	,,	,,	957
52·63	1n	,,	,,	959·2
52·24	1n	,,	,,	961·1
51·87	1n	,,	,,	962·9
51·31	1n	,,	,,	965·6
50·68	1n	,,	,,	968·6
50·55	1n	,,	,,	969·2
50·05	2	,,	,,	971·7
49·4	1n	,,	,,	975
48·75	1n	,,	,,	977·9
48·4	1n	,,	,,	980
48·2	1n	,,	,,	980·5
47·65	1n	,,	,,	983·3
46·43	1	,,	,,	989·2
45·76	4	,,	,,	992·4
45·16	1	,,	,,	995·3
45·01	1	,,	,,	996·1
44·57	1	,,	,,	998·2
43·83	7	,,	,,	22001·8
43·21	1n	,,	,,	004·8
42·75	1n	1·24	,,	007·0
42·25	1n	,,	,,	009·4
41·90	1	,,	,,	011·1
40·70	1	,,	,,	016·9
40·41	1	,,	,,	018·3
39·4	1n	,,	,,	023
38·37	4	,,	,,	028·2
37·35	1	,,	,,	033·2
37·0	1n	,,	,,	035

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4536·80	1	1·24	6·1	22035·9
36·24	1	,,	,,	038·6
35·45	1n	,,	,,	042·4
35·32	1n	,,	,,	043·4
34·73	1n	,,	,,	045·9
33·91	1	,,	,,	049·9
33·25	1n	,,	,,	053·1
32·7	1b	,,	,,	056
31·95	1n	,,	,,	059·5
31·50	1n	,,	,,	061·6
30·93	1n	,,	,,	064·3
29·92	1	,,	,,	069·3
29·3	1b	,,	,,	072
28·74	1d	,,	,,	075·1
28·20	1	,,	,,	077·7
27·85	1	,,	,,	079·4
26·85	1	,,	,,	084·2
26·20	1n	,,	,,	087·4
25·98	1	,,	,,	088·6
25·87	1	,,	,,	089·1
25·57	1	,,	,,	090·6
25·14	1	,,	,,	092·7
24·3	1b	,,	,,	097
23·43	1	,,	,,	101·0
23·1	1b	,,	,,	103
21·81	2n	,,	,,	108·9
20·7	1n d	,,	,,	114
19·97	1n	,,	,,	117·9
19·4	1n	,,	,,	121
18·80	1n	,,	,,	123·6
18·30	1n	,,	,,	126·1
17·45	1	,,	,,	130·2
16·95	1	,,	,,	132·7
15·8	2b	,,	,,	138
15·50	4	,,	,,	139·8
14·49	1	,,	,,	144·8
14·30	1	,,	,,	145·7
13·89	1	,,	,,	147·7
13·55	1	,,	,,	149·3
13·04	1	,,	,,	151·8
12·62	1	,,	,,	154·0
12·37	1	,,	,,	155·2
11·98	1	,,	,,	157·1
11·88	1	,,	,,	157·6
11·46	1	,,	,,	159·6
10·53	3	,,	,,	164·2
10·08	1	,,	,,	166·4
09·55	1n	,,	,,	168·9
09·1	1b	,,	,,	171
08·4	1b	,,	,,	172
07·96	1	,,	,,	174·9
07·67	1	,,	,,	176·7
06·85	1n	,,	,,	881·8
06·42	2	,,	,,	184·5
06·31	2	,,	,,	185·0

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4504·95	1	1·23	6·1	22191·7
04·47	1n	,,	,,	193·1
03·97	1	,,	,,	196·5
03·86	1	,,	,,	197·0
02·56	1n	,,	,,	203·5
02·11	1	,,	,,	205·7
01·65	1n	,,	,,	208·0
00·9	1n	,,	,,	212
00·00	1n	,,	,,	216·1
4499·87	1n	,,	,,	216·7
99·40	1	,,	,,	219·1
98 47	1n d	,,	,,	223·7
97·7	1b	,,	,,	227·5
96·83	1n	,,	,,	231·8
96·35	1n	,,	,,	234·2
95·85	1n	,,	,,	236·6
95·5	1n	,,	6·2	238
95·3	1n	,,	,,	239
94·90	1	,,	,,	241·2
94·09	1n	,,	,,	245·2
93·28	1	,,	,,	249·3
92·60	1	,,	,,	252·6
92·20	1	,,	,,	254·7
91·71	1	,,	,,	257·1
91·53	1	,,	,,	257·9
91·02	3	,,	,,	260·4
90·4	1b	,,	,,	263
89·29	1	,,	,,	269·9
89·1	1n	,,	,,	270
88·40	1	,,	,,	273·6
87·90	1n	,,	,,	276·0
87·27	1	,,	,,	279·2
87·15	1	,,	,,	280·0
86·52	1	,,	,,	282·9
86·12	1	,,	,,	284·8
85·40	1	,,	,,	288·3
84·7	1b	,,	,,	291
83·99	1	,,	,,	294·3
83·67	1	,,	,,	295·8
82·91	1	,,	,,	300·8
82·4	1b	,,	,,	303
81·25 *	1n	,,	,,	309·0
80·83	1n	,,	,,	311·0
80·55	1n	,,	,,	312·4
79·63	1n	,,	,,	316·7
79·15	1n	,,	,,	318·9
77·93	2	,,	,,	325 9
77·67	1n	,,	,,	327·1
76·70	1	,,	,,	331·7
75·91	1	,,	,,	335·8
75·50	1n	,,	,,	337·7
75·04	1n	,,	,,	339·8
74·73	1n	,,	,,	341·3

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4474·5	1n	1·23	6·2	22342·5
74·4	1n	,,	,,	343
74·0	1b	,,	,,	345
73·6	1b	,,	,,	347
72·55	6	,,	,,	352·4
71·82	1	,,	,,	357·7
70·65	1n	,,	,,	363·3
70·50	1	,,	,,	362·6
70·0	1n	,,	,,	365
69·52	1	,,	,,	367·6
69·42	1	,,	,,	368·1
69·05	1	,,	,,	369·9
68·57	1	1·22	,,	372·3
68·49	1	,,	,,	372·7
68·34	1	,,	,,	373·5
68·16	1	,,	,,	374·4
68·03	1	,,	,,	375·0
67·55	1	,,	,,	377·5
67·27	1	,,	,,	378·8
66·5	1b	,,	,,	383
65·92	1	,,	,,	385·7
65·35	3	,,	,,	388·5
64·50	1	,,	,,	392·7
64·38	1	,,	,,	393·3
63·98	1	,,	,,	395·4
63·19	3	,,	,,	399·7
62·99	1	,,	,,	400·8
62·59	1	,,	,,	402·3
62·45	1	,,	,,	403·0
62·04	1	,,	,,	405·1
61·62	1	,,	,,	407·2
61·13	1	,,	,,	409·7
60·77	1	,,	,,	411·5
59·97	1n	,,	,,	415·5
58·85	1n d	,,	,,	421·1
58·15	1n	,,	,,	424·6
58·03	1	,,	,,	425·2
57·67	1	,,	,,	427·0
57·33	1	,,	,,	428·7
57·0	1n	,,	,,	430
56·44	1	,,	,,	433·2
56·08	1	,,	,,	435·1
55·3	1n	,,	,,	439
54·1	1n	,,	,,	445
53·95	1n	,,	,,	445·7
53·68	1	,,	,,	447·1
53·46	1	,,	,,	448·2
52·48	1	,,	,,	453·1
52·19	1	,,	,,	454·6
51·72	1	,,	,,	456·9
51·18	1n	,,	,,	459·6
50·75	2	,,	,,	461·9
50·59	2	,,	,,	462·7
49·74	1	,,	,,	467·0
49·2	1b	,,	,,	470

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}$ −	
4448·5	1b	1·22	6·2	22473
48·2	1b	,,	,,	475
47·30	2	,,	,,	479·2
46·18	1	,,	,,	484 8
45·70	1d	,,	,,	487·4
45·38	1	,,	,,	489·1
44·90	1	,,	,,	491·5
43·80	1	,,	,,	497·1
43·60	1	,,	,,	498·1
43·47	1	,,	,,	498·8
42·95	1n	,,	,,	501·4
42·80	1n	,,	,,	502·1
42·20	1n	,,	,,	505·2
41·75	1n	,,	,,	507·5
41·29	1	,,	,,	509·8
41·20	1	,,	,,	510·3
40·94	1	,,	,,	511·6
40·54	1	,,	,,	513·6
40·22	1n	,,	,,	515·3
39·32	1	,,	,,	519·8
38·90	1	,,	,,	521·9
38·61	1	,,	,,	523·3
38·42	1n	,,	,,	524·3
38·16	1n	,,	,,	525·7
37·12	1n	,,	,,	530·9
36·97	1	,,	,,	531·7
36·5	1n	,,	,,	534
35·72	1n	,,	,,	538·0
34·81	2	,,	,,	542·7
34·08	3	,,	,,	546·4
33·58	1n	,,	,,	548·9
33·35	1n	,,	,,	550·1
32·90	1	,,	,,	552·4
32·60	1	,,	,,	553·9
32·2	1b	,,	,,	556
31·8	1b	,,	6·3	558
30·27	1	1·21	,,	565·7
29·79	1	,,	,,	568·1
29·05	1	,,	,,	571·9
28·53	1	,,	,,	574·5
27·81	3	,,	,,	578·2
27·14	1	,,	,,	581·6
26·85	2	,,	,,	583·1
26·25	1	,,	,,	586·2
26·03	1	,,	,,	587·3
25·6*	1n	,,	,,	589·5
25·35	1n	,,	,,	590·8
24·73	1n	,,	,,	593·9
23·96	2	,,	,,	597·8
23·49	1	,,	,,	600·3
23·15	1	,,	,,	602·0
22·78	1	,,	,,	603·9
22·2	1n	,,	,,	607

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
4420·89	2n	1·21	6·3	22613·6
20·57	1	,,	,,	615·2
19·8	1n	,,	,,	620
19·3	1n	,,	,,	620
18·68	1	,,	,,	624·9
18·22	1	,,	,,	627·2
17·94	1	,,	,,	628·7
17·61	1	,,	,,	630·3
17·00	1	,,	,,	633·5
16·73	1	,,	,,	634·9
16·05	1	,,	,,	638·3
15·46	2	,,	,,	641·4
14·97	1	,,	,,	643·9
14·85	1	,,	,,	644·5
14·50	1	,,	,,	646·3
13·33	1	,,	,,	652·3
13·07	1	,,	,,	653·7
12·7	1n	,,	,,	656
12·5	1n	,,	,,	657
12·0	1n	,,	,,	659
11·65	1	,,	,,	661·0
11·50	1	,,	,,	661·7
11·31	1	,,	,,	662·7
11·10	1	,,	,,	663·8
10·6	1n	,,	,,	666
10·3	1n	,,	,,	668
09·90	1	,,	,,	669·9
09·1	1n	,,	,,	674
08·92	1	,,	,,	675·0
08·73	1	,,	,,	676·0
08·15	1	,,	,,	679·0
07·4	1n	,,	,,	683
06·74	1	,,	,,	686·2
06·13	1	,,	,,	689·4
06·0	1n	,,	,,	690
05·47	1	,,	,,	692·7
05·09	1	,,	,,	694·7
04·99*	1	,,	,,	695·7
04·53	1	,,	,,	697·6
04·22	1	,,	,,	699·2
03·52	1	,,	,,	702·8
02·70	1	,,	,,	707·1
02·57	1	,,	,,	707·7
02·06	1	,,	,,	710·4
01·1	1n	,,	,,	715
00·65	1n	,,	,,	717·6
4399·81	1	,,	,,	721·8
98·0	1n	,,	,,	731
97·50	1	,,	,,	733·9
95·96	1n	,,	,,	741·8
95·45	1n	,,	,,	744·5
95·1	1n	,,	,,	746
94·83	1	1·20	,,	747·7

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4393·80	2	1·20	6·3	22753·0
92·73	1	,,	,,	758·6
92·40	1	,,	,,	760·3
92·04	1	,,	,,	762·1
91·69	1	,,	,,	763·9
91·46	1	,,	,,	765·1
91·30	1	,,	,,	766·0
91·1	1n	,,	,,	767
90·74	1	,,	,,	768·8
90·50	1	,,	,,	770·1
90·36	1	,,	,,	770·8
90·20	1	,,	,,	771·6
88·9	1n	,,	,,	778
88·4	1n	,,	,,	781
87·95	1n	,,	,,	783·3
87·8	1n	,,	,,	784
87·45	1n	,,	,,	785·9
86·9*	1n	,,	,,	789
86·35	1n	,,	,,	791·6
86·21	1n	,,	,,	792·4
85·76	1n	,,	,,	794·8
84·95	1	,,	,,	799·0
84·82	1	,,	,,	799·7
83·77	2	,,	,,	805·2
83·50	2	,,	,,	806·5
82·60	1	,,	,,	811·2
82·32	1	,,	,,	812·7
82·04	1	,,	,,	814·1
81·60	1	,,	,,	816·4
81·35	1	,,	,,	817·7
80·95	1	,,	,,	819·8
80·49	1	,,	,,	822·2
79·9	1n	,,	,,	825
79·41	1	,,	,,	827·9
78·75	1n	,,	,,	831·3
78·50	1n	,,	,,	832·6
78·0	1n	,,	,,	835
77·48	1n	,,	,,	837·9
77·00	1	,,	,,	840·4
76·37	1n	,,	,,	843·7
75·95	1	,,	,,	845·9
75·79	1n	,,	,,	846·7
74·22	1	,,	,,	854·9
73·61	2	,,	,,	858·1
72·95	1n	,,	,,	861·6
72·78	2	,,	,,	862·5
71·99	2	,,	,,	866·6
71·26	1	,,	,,	870·3
70·21	1	,,	,,	875·9
69·75	1n	,,	,,	878·3
69·5	1n	,,	,,	880
69·0	1n	,,	,,	882
68·42	1	,,	6·4	885·2

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4368·33	1	1·20	6·4	22885·7
67·95	1	,,	,,	887·7
67·6	1n	,,	,,	889·5
65·77	1	,,	,,	899·2
65·28	1	,,	,,	901·7
65·18	1	,,	,,	902·3
65·00	1	,,	,,	903·1
64·61	1	,,	,,	905·2
64·50	1	,,	,,	905·7
64·03	1	,,	,,	908·1
63·15	2	,,	,,	912·8
63·00	1	,,	,,	913·6
62·48	3	,,	,,	916·3
62·23	2	,,	,,	917·6
61·36	1	,,	,,	922·2
61·2	1n	,,	,,	923
60·45	1n	,,	,,	927·1
59·92	1n	,,	,,	929·8
59·68	1n	,,	,,	931·1
59·10	1	,,	,,	934·2
58·83	1	,,	,,	935·6
58·60	1	,,	,,	936·8
58·36	1	,,	,,	938·0
58·0	1n	,,	,,	940
57·8	1n	,,	,,	941
57·06	1	,,	,,	944·9
56·75	1	1·19	,,	946·5
55·89	4	,,	,,	951·1
54·77	2	,,	,,	957·0
54·53	2	,,	,,	958·3
54·25	1	,,	,,	959·7
53·95	1	,,	,,	961·4
53·3	1n	,,	,,	965
52·98	1	,,	,,	966·5
52·62	1	,,	,,	968·4
52·30	1	,,	,,	970·1
51·98	1	,,	,,	971·7
51·84	1	,,	,,	972·4
50·5	1n	,,	,,	979
50·3	1n	,,	,,	980
50·1	1n	,,	,,	982
49·8	1n	,,	,,	983
48·8	1n	,,	,,	988
48·32	1	,,	,,	989·6
47·36	3	,,	,,	996·1
46·95	1	,,	,,	998·2
46·48	1	,,	,,	23000·7
46·20	1	,,	,,	002·2
44·88	1	,,	,,	009·2
44·45	1	,,	,,	011·4
44·15	1	,,	,,	013·1
43·5	1n	,,	,,	016·5
42·60	1	,,	,,	021·3
41·89	4	,,	,,	025·0
40·86	1n	,,	,,	030·5

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4340·63	1	1·19	6·4	23031·8
39·94	1	,,	,,	035·4
39·55	1	,,	,,	037·4
39·16	1d	,,	,,	039·5
38·93	1	,,	,,	040·7
38·80	1	,,	,,	041·4
38·48	1	,,	,,	043·1
38·1	1b	,,	,,	045
37·61	1	,,	,,	047·7
36·93	1n	,,	,,	051·3
36·60	2n	,,	,,	053·0
35·92	2n	,,	,,	056·8
35·44	1	,,	,,	059·3
35·13	1	,,	,,	060·9
34·66	1	,,	,,	063·4
33·71	1	,,	,,	068·5
33·15	1	,,	,,	071·5
32·47	1	,,	,,	075·1
32·05	1	,,	,,	077·4
31·63	1	,,	,,	079·6
30·9	1b	,,	,,	083·5
30·20	1n	,,	,,	087·2
29·7	1b	,,	,,	090
29·40	1	,,	,,	091·5
28·92	1	,,	,,	094·0
28·35	1	,,	,,	097·1
28·0	1b	,,	,,	099
27·18	2	,,	,,	103·4
36·06	3	,,	,,	109·3
25·32	1	,,	,,	113·2
24·90	1	,,	,,	115·5
24·75	1	,,	,,	116·3
23·92	2	,,	6·5	220·8
22·55	1n	,,	,,	128·2
22·2	1b	,,	,,	120
21·51	1	,,	,,	133·8
21·2	1b	,,	,,	135
20·6	1b	,,	,,	138·5
19·97	2	,,	,,	141·8
19·67	1	,,	,,	143·4
19·22	1	,,	,,	145·9
18·5	1b	1·18	,,	150
18·2	1b	,,	,,	151
17·78	1	,,	,,	153·6
17·46	1	,,	,,	155·4
17·27	1	,,	,,	156·4
16·70	1	,,	,,	159·4
16·20	1n	,,	,,	162·1
16·08	1n	,,	,,	162·7
15·7	1n	,,	,,	165
15·4	1n	,,	,,	166
14·08	2	,,	,,	173·4
13·39	2n	,,	,,	177·1
12·87	1	,,	,,	179·9
12·51	1	,,	,,	181·8

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4311·95	1n	1·18	6·5	23185·0
11·65	1n	,,	,,	186·6
11·3	1b	,,	,,	187
10·62	1	,,	,,	191·1
09·95	1	,,	,,	195·8
09·40	1n	,,	,,	198·7
08·8	1b	,,	,,	202
08·13	1n	,,	,,	205·5
07·50	1	,,	,,	208·8
07·06	1	,,	,,	211·1
06·99	1	,,	,,	211·5
06·71	1	,,	,,	213·0
06·48	1	,,	,,	214·3
06·1	1n	,,	,,	216
05·4	1n	,,	,,	220
04·9	1n	,,	,,	223
04·67	1	,,	,,	224·0
04·25	1n	,,	,,	226·3
03·53	1	,,	,,	230·3
03·43	1	,,	,,	230·8
03·00	1	,,	,,	233·1
02·60	1	,,	,,	235·2
02·51	1	,,	,,	235·7
02·30	1	,,	,,	236·8
01·9	1n	,,	,,	239
01·70	1	,,	,,	240·1
01·60	1	,,	,,	240·7
01·05	1n	,,	,,	243·7
00·95	1n	,,	,,	244·2
00·53	1	,,	,,	246·5
00·26	1	,,	,,	247·9
00·08	1	,,	,,	248·9
4299·61	2	,,	,,	251·4
99·26	1n	,,	,,	253·3
99·05	1n	,,	,,	254·3
98·6	1n	,,	,,	257
98·2	1n	,,	,,	260
97·78	1	,,	,,	261·4
97·31	3	,,	,,	263·9
96·77	1	,,	,,	266·8
96·49	1	,,	,,	268·3
95·93	1	,,	,,	271·3
95·47	1	,,	,,	273·8
95·32	1	,,	,,	274·6
94·85	1	,,	,,	277·2
94·40	1n	,,	,,	279·6
94·13	1	,,	,,	281·1
93·95	1n	,,	,,	282·1
93·53	1	,,	,,	284·4
92·87	1n	,,	,,	287·9
91·81	1	,,	,,	293·7
91·08	2	,,	,,	297·6
90·05	2	,,	,,	299·1
89·72	1	,,	,,	305·1
89·05	2	,,	,,	308·7

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4288·56	1	1·18	6·5	23311·4
88·05	3	,,	,,	314·2
87·10	3	,,	,,	319·3
86·5	1n	,,	,,	322·5
85·96	1	,,	,,	325·4
85·63	1	,,	,,	327·2
85·45	1	,,	,,	328·2
85·20	1	,,	,,	329·6
85·03	1	,,	,,	330·5
84·73	1	,,	,,	332·2
84·15	1n	,,	,,	335·3
83·65	1n	,,	,,	338·1
83·3	1n	,,	,,	340
82·67	3	,,	,,	343·5
82·25	3	,,	,,	345·8
82·00	1	,,	,,	347·1
81·5	1n	,,	,,	350
80·86	1n	1·17	,,	354·7
80·4	1n	,,	,,	356
79·53	1n	,,	,,	360·6
78·37	2	,,	,,	367·0
77·76	1	,,	,,	370·3
77·43	1n	,,	,,	372·1
77·08	1	,,	,,	374·1
76·69	2	,,	,,	376·2
76·2	1n	,,	,,	379
75·94	1	,,	,,	380·1
75·46	1	,,	,,	382·8
75·2	1n	,,	,,	384
74·20	3	,,	,,	389·7
73·64	1	,,	,,	392·8
73·16	1n	,,	,,	395·4
72·52	1	,,	,,	398·9
72·03	1n	,,	,,	401·6
71·46	1	,,	,,	404·8
71·12	1	,,	,,	406·6
70·88	1	,,	,,	407·9
70·50	1d	,,	,,	410·0
69·84	4	,,	,,	413·6
69·05	2	,,	,,	418·0
68·67	1	,,	,,	420·1
68·22	1	,,	,,	422·5
68·12	1	,,	,,	423·0
67·76	1	,,	,,	425·0
67·50	2	,,	,,	426·4
66·89	1	,,	,,	429·8
66·53	1n	,,	,,	431·8
65·8	1n	,,	,,	436
65·45	1	,,	,,	437·7
64·95	1	,,	,,	440·5
64·49	1	,,	,,	443·1
64·05	1	,,	,,	445·4
63·97	1	,,	,,	445·8
63·66	1	,,	,,	447·5
63·38	1	,,	,,	449·0

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
4263·12	1	1·17	6·5	23450·5
62·75	1	,,	,,	452·6
62·40	1n	,,	,,	454·5
61·73	1	,,	,,	458·2
61·25	1n	,,	,,	460·8
61·1	1n	,,	,,	462
59·65	1	,,	,,	469·6
59·43	2	,,	,,	470·8
59·10	1	,,	,,	472·6
58·7	1n	,,	,,	475
58·45	1n	,,	,,	476·2
58·3	1n	,,	,,	477
57·9	1n	,,	,,	479
57·21	1	,,	,,	483·1
56·75	1n	,,	,,	485·7
55·95	1	,,	,,	490·0
55·65	1	,,	,,	491·7
55·50	1	,,	,,	492·5
55·0	1n	,,	,,	495
54·6	1n	,,	,,	497
54·45	1n	,,	,,	498·3
54·10	1	,,	,,	500·2
53·9	1n	,,	,,	501
52·65	2	,,	6·6	508·2
52·30	1n	,,	,,	510·2
51·9	1n	,,	,,	512
51·60	1n	,,	,,	514·1
51·1	1b	,,	,,	517
50·42	1n	,,	,,	520·5
50·2	1n	,,	,,	522
49·73	1	,,	,,	524·3
49·3	1b	,,	,,	527
48·8	1b	,,	,,	529
48·13	1	,,	,,	533·1
47·57	1	,,	,,	536·2
47·33	1	,,	,,	537·6
46·45	2	,,	,,	542·5
46·18	1	,,	,,	544·0
45·96	1	,,	,,	545·2
45·60	1	,,	,,	547·2
45·10	1	,,	,,	550 0
44·53	3	,,	,,	553·2
43·53	1	1·16	,,	558·7
43·25	1	,,	,,	560·2
42·70	1	,,	,,	563·3
42·52	1	,,	,,	564·3
41·88	4	,,	,,	567·8
40·80	2	,,	,,	573·8
40·35	1n	,,	,,	576·3
39·9	1n	,,	,,	579
39·33	1	,,	,,	582·1
38·8	1b	,,	,,	585
37·93	1n	,,	,,	589·8
36·62	1	,,	,,	597·1
36·21	3	,,	,,	599·4

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4235·60	1	1·17	6 6	23602·8
34·90	1	,,	,,	606·7
34·77	1	,,	,,	607·4
34·25	1	,,	,,	610·3
33·92	1	,,	,,	612·2
33·70	1	,,	,,	613·4
33·32	1	,,	,,	615·5
32·58	1	,,	,,	619·7
32·23	2	,,	,,	621·6
31·86	2	,,	,,	623·7
31·40	1n	,,	,,	626·2
30·5	1n	,,	,,	631
30·0	1n	,,	,,	634
29·9	1n	,,	,,	635
29·45	1	,,	,,	637·1
28·95	2	,,	,,	639·9
28·57	1	,,	,,	642·1
27·50	2	,,	,,	648·0
26·90*	2n	,,	,,	651·4
26·25	1	,,	,,	655·0
25·97	1	,,	,,	656·6
25·55	2n	,,	,,	659·0
24·5	1b	,,	,,	666
23·8	1n	,,	,,	669
23·50	1n	,,	,,	670·4
23·13	1	,,	,,	672·5
22·90	1	,,	,,	673·8
22·57	1	,,	,,	675·6
22·32	1	,,	,,	677·0
21·99	1	,,	,,	678·8
21·4	1n	,,	,,	682
20·87	1	,,	,,	685·2
20·30	1	,,	,,	688·4
20·20	1	,,	,,	689·0
19·89	1	,,	,,	690·7
19·70	1	,,	,,	691·7
19·5	1n	,,	,,	693
18·55	1n	,,	,,	698·2
18·3	1n	,,	,,	700
17·93	1	,,	,,	701·7
17·65	1	,,	,,	703·3
17·3	1n	,,	,,	704
17·0	1n	,,	,,	707
16·75	1	,,	,,	708·3
16·47	1	,,	,,	709·9
16·17	1	,,	,,	711·6
15·69	1	,,	,,	714·3
15·44	1	,,	,,	715·7
15·20	1	,,	,,	717·1
14·61	1	,,	,,	720·4
14·51	1	,,	,,	721·0
14·10	2	,,	,,	723·3
13·9	1n	,,	,,	724

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4213·50	1	1·17	6·6	23726·6
13·19	1	,,	,,	728·3
12·94	1	,,	,,	729·7
12·67	1	,,	,,	731·3
12·47	2	,,	,,	732·4
12·35	1	,,	,,	733·1
11·87	2	,,	,,	735·8
11·52	1	,,	,,	737·7
11·05	1d	,,	,,	740·4
10·64	2	,,	,,	742·7
09·7	1b	,,	,,	748
07·4	1b	,,	,,	761
06·54	1d	,,	,,	765·8
06·14	1	,,	,,	768·2
05·2	1n	1·15	,,	773·5
04·63	1	,,	,,	776·7
04·51	2	,,	,,	777·4
03·27	1	,,	,,	784·4
02·9	1n	,,	,,	786·5
02·60	1n	,,	,,	788·2
02·45	1n	,,	,,	789·0
01·80	1n	,,	,,	792·7
01·59	1	,,	,,	793·8
01·30	1	,,	,,	795·5
01·13	1	,,	,,	796·4
00·30	2	,,	6·7	801·1
4199·8	1n	,,	,,	804
98·9	1n	,,	,,	809
98·39	1	,,	,,	812·0
97·69	2d ?	,,	,,	816·0
97·35	1n	,,	,,	817·9
96·9	1n	,,	,,	820
96·70	1	,,	,,	821·5
96·0	1n	,,	,,	825·5
95·7	1n	,,	,,	827
95·4	1n	,,	,,	829
95·22	1n	,,	,,	829·9
94·55	1	,,	,,	833·7
94·15	1n	,,	,,	836·0
93·95	1n	,,	,,	837·2
93·60	1n	,,	,,	839·1
93·15	1n	,,	,,	841·6
92·35	1n	,,	,,	846·3
92·15	1	,,	,,	847·4
91·76	1	,,	,,	849·6
90·5	1b	,,	,,	857
89·40	2	,,	,,	863·1
89·0	1n	,,	,,	865
88·33	2	,,	,,	869·1
88·02	1	,,	,,	870·9
87·57	1	,,	,,	873·5
87·15	1	,,	,,	875·9
86·95	1	,,	,,	877·0
86·63	1	,,	,,	878·9
86·22	1	,,	,,	881·3

URANIUM —*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4185·97	1	1·15	6·7	23882·7
85·85	1	,,	,,	883 4
85·04	1	,,	,,	887·9
84·67	1n	,,	,,	890·0
84·27	1n	,,	,,	892·3
83·79	1	,,	,,	895·0
83·47	1	,,	,,	896·9
83·15	1	,,	,,	898·7
82·88	1	,,	,,	900·2
81·75	1	,,	,,	906·8
80·90	1	,,	,,	911·6
80·53	1n	,,	,,	913·7
80·3	1n	,,	,,	915
79·20	2	,,	,,	921·3
78·69	1	,,	,,	924·2
78·00	1	,,	,,	928·2
77·56	1	,,	,,	930·7
77·1	1n	,,	,,	933
76·75	1n	,,	,,	935·4
76·11	1	,,	,,	939·1
75·63	1	,,	,,	941·8
74·40	2	,,	,,	948·7
74·01	1	,,	,,	950·9
73·90	1	,,	,,	951·7
73·19	2	,,	,,	955·8
72·8	1n	,,	,,	958
72·40	1	,,	,,	960·3
71·80	3	,,	,,	963·8
71·00	1	,,	,,	968·4
70·60	1n	,,	,,	970·7
70·17	1	,,	,,	973·1
69·7	1n	,,	,,	976
69·25	1	,,	,,	978·4
68·3	1b	1·14	,,	984
67·87	1n	,,	,,	986·4
67·25	1n	,,	,,	989·9
66·8	1n	,,	,,	992·5
65·87	2	,,	,,	997·9
65·35	1n	,,	,,	24000·9
64·97	1	,,	,,	003·1
64·6	1n	,,	,,	005
63·90	2	,,	,,	009·2
63·44	1	,,	,,	011·8
63·22	1	,,	,,	013·1
62·88	1	,,	,,	015·1
62·62	1	,,	,,	016·6
62·00	2	,,	,,	020·2
61·14	1	,,	,,	025·1
60·5	1b	,,	,,	029
60·05	1	,,	,,	031·5
59·59	1	,,	,,	034·2
59·30	1	,,	,,	035·9
59·15	1	,,	,,	036·8
58·8	1n	,,	,,	039
58·48	2	,,	,,	040·5

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4156·81	2	1·14	6·7	24050·2
55·58	3	,,	,,	051·3
54·16	2	,,	,,	064·5
53·75	2	,,	,,	066·8
51·83	1	,,	,,	079·0
51·48	1	,,	,,	081·1
51·00	1	,,	,,	083·9
50·61	2	,,	,,	086·1
50·25	1n	,,	,,	088·2
49·57	1n	,,	,,	092·2
49·38	1n	,,	,,	093·3
48·97	1	,,	,,	095·7
48·76	1	,,	,,	096·9
48·33	1n	,,	,,	099·3
47·62	1	,,	,,	103·4
47·30	1	,,	6·8	105·3
47·20	1	,,	,,	105·9
46·83	1	,,	,,	108·1
46·45	1	,,	,,	110·4
45·58	2	,,	,,	115·5
44·92	1	,,	,,	119·1
44·15	1n	,,	,,	123·6
43·76	1	,,	,,	125·9
43·19	1	,,	,,	129·2
42·59	1	,,	,,	133·2
42·42	1	,,	,,	133·7
42·32	1	,,	,,	134·3
42·09	1	,,	,,	135·6
41·45	3	,,	,,	139·3
40·80	1n	,,	,,	143·1
40·53	1n	,,	,,	144·7
39·34	2	,,	,,	151·7
38·84	1	,,	,,	154·6
38·15	1	,,	,,	158·6
37·00	1	,,	,,	165·3
36·68	1	,,	,,	167·2
36·32	1	,,	,,	169·3
35·97	1	,,	,,	171·3
35·39	1	,,	,,	174·7
35·03	1	,,	,,	176·8
34·23	1n	,,	,,	181·5
33·71	2	,,	,,	184·5
33·40	2	,,	,,	186·3
32·30	1	,,	,,	192·8
31·98	1	1·13	,,	194·7
31·55	1	,,	,,	197·2
30·89	1	,,	,,	201·1
29·9	1n	,,	,,	207
29·65	1n	,,	,,	208·3
29·18	1	,,	,,	211·0
28·52	2	,,	,,	215·0
28·13	1	,,	,,	217·2
27·65	1d	,,	,,	220·1
27·05	1n	,,	,,	223·6
26·6	1b	,,	,,	226

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4125·3	1n	1·13	6·8	24234
24·92	3	,,	,,	236·1
24·19	1	,,	,,	240·4
23·83	1	,,	,,	242·5
23 5	1n	,,	,,	244
23·3	1n	,,	,,	246
22·58	1n	,,	,,	249 9
22·39	1n	,,	,,	251·0
21·45	1n	,,	,,	256·5
21·0	1n	,,	,,	259
20·3	1n	,,	,,	263
19·90	1n	,,	,,	265·6
19·1	1n	,,	,,	270
18·59	2	,,	,,	273·4
17·75	1n	,,	,,	278·3
17·10	1	,,	,,	282·1
16·6	1n	,,	,,	285
16·30	3	,,	,,	286·9
15·10	1	,,	,,	293·9
14·82	1	,,	,,	295·6
14·42	1	,,	,,	298·0
14·18	1	,,	,,	299·3
14·10	1	,,	,,	299·9
13·77	1	,,	,,	301·8
13·27	1	,,	,,	304·8
12·95	1	,,	,,	306·6
12·70	1	,,	,,	308·1
11·8	1b	,,	,,	313
11·05	1	,,	,,	317·9
10·7	1n	,,	,,	320
10·20	1	,,	,,	322·9
08·9	1n	,,	,,	331
08·60	1	,,	,,	332·4
07·11	1	,,	,,	341·2
06·52	2	,,	,,	344·7
06·08	1	,,	,,	347·4
05·9	1n	,,	,,	348
05·48	1n	,,	,,	350·8
04·95	1n	,,	,,	354·0
04·58	1n	,,	,,	356·2
04·22	1n	,,	,,	358·3
03·73	1	,,	,,	361·3
03·29	1	,,	,,	363·9
02·98	1	,,	,,	367·0
02·41	1	,,	,,	369·0
02·10	1	,,	,,	371·0
01·5	1n	,,	,,	374·5
00·67	1	,,	,,	379·4
00·10	1	,,	,,	382·8
4099·45	1n	,,	,,	386·7
99·2	1b	,,	6·9	388
98·30	1	,,	,,	393·4
98·20	1	,,	,,	394·1
97·9	1n	,,	,,	396
97·55	1n	,,	,,	397·9

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4097·23	1	1·13	6·9	24399·7
96·93	1	”	”	401·5
96·83	1	”	”	402·2
96·56	1	”	”	403·9
95·90	1	”	”	407·8
95·8	1n	”	”	408
95·03	1	”	”	412·9
94·75	1	”	”	414·6
94·2	1b	”	”	418
93·80	1n	1·12	”	420·3
93·43	1n	”	”	422·5
92·97	1n	”	”	425·2
92·47	1n	”	”	428·1
92·05	1n	”	”	430·8
91·66	2d	”	”	432·2
90·28	4	”	”	440·3
88·98	1	”	”	449·1
88·40	2	”	”	452·5
87·87	1	”	”	455·6
87·51	1	”	”	457·7
86·92	1	”	”	461·2
86·83	1	”	”	461·8
86·63	1	”	”	463·4
86·28	1	”	”	465·4
85·1	2n	”	”	472
84·69	1	”	”	474·7
84·31	1	”	”	476·4
83·85	1n	”	”	479·6
83·15	1n	”	”	484·0
82·80	1	”	”	486·1
82·20	1	”	”	489·7
81·45	1	”	”	494·1
80·79	3	”	”	498·2
80·05	1n	”	”	502·6
79·51	1	”	”	505·8
79·00	1	”	”	508·9
78·35	1n	”	”	502·8
77·95	1	”	”	505·4
76·86	2	”	”	521·9
76·3	1b	”	”	525
75·83	1n	”	”	528·0
74·68	1d	”	”	534·9
73·93	1	”	”	539·4
73·80	1	”	”	540·2
73·3	1n	”	”	543
73·00	1	”	”	545·0
72·20	1	”	”	549·9
71·63	1	”	”	553·4
71·30	2	”	”	555·3
70·9	1n	”	”	558
70·6	1n	”	”	559·5
70·20	1	”	”	561·9
69·90	1	”	”	563·7
69·23	1	”	”	567·8
69·15	1	”	”	568·2

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4068·75	1	1·12	6·9	24570·7
67·90	2	,,	,,	575·8
67·33	1	,,	,,	579·2
66·97	1	,,	,,	581·4
66·65	1	,,	,,	583·4
66·4	1n	,,	,,	585
66·2	1n	,,	,,	586
66·0	1n	,,	,,	587
64·32	2	,,	,,	597·4
63·78	1	,,	,,	600·7
63 26	1	,,	,,	603·8
62·72	2	,,	,,	607·2
61·90	1	,,	,,	612·1
61·51	1	,,	,,	614·5
61·10	1n	,,	,,	617·0
60·38	1	,,	,,	621·3
60·28	1	,,	,,	622·0
59·8	1b	,,	,,	625
59·3	1b	,,	,,	628
59·0	1b	,,	,,	630
58·35	2	,,	,,	633·4
58·05*	1n	,,	,,	635·5
57·5	1b	,,	,,	639
56·55	1	,,	,,	644·4
56·20	1	,,	,,	646·7
55·86	1	,,	,,	648·8
55·3	1b	,,	,,	652
54·99	1	1·11	,,	654·1
54·87	1	,,	,,	654·8
54·46	1	,,	,,	657·3
53·8	1n	,,	,,	661
53·20	1	,,	,,	665·0
52·65	1n	,,	,,	668·3
52·2	1n	,,	,,	671
52·07	2	,,	,,	671·8
51·3	1n	,,	7·0	676
51·1	1n	,,	,,	678
50·21	3	,,	,,	683·1
49·95	1	,,	,,	684·7
49·70	1	,,	,,	686·2
49·40	1n	,,	,,	688·0
48·70	1	,,	,,	692·3
48·25	1	,,	,,	695·0
47·78	1	,,	,,	697·9
47·26	1	,,	,,	701·2
46·2	1b	,,	,,	708
45·99†	2	,,	,,	708·8
45·40	1	,,	,,	712·4
45·10	1	,,	,,	714·3
44·63	2	,,	,,	717·1
44·2	1b	,,	,,	720
43·4	1b	,,	,,	725
42·96	1	,,	,,	727·4

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4042·63	1	1·11	7·0	24729·4
42·15	1n	,,	,,	732·3
41·78	1n	,,	,,	734·6
41·23	1n	,,	,,	738·0
40·6	1n	,,	,,	742
39·9	1n	,,	,,	746
38·8	1b	,,	,,	753
38·36	1n	,,	,,	755·5
38·10	1	,,	,,	757·1
37·2	1b	,,	,,	763
36·75	2n	,,	,,	765·8
36·3	1n	,,	,,	768
35·8	1n	,,	,,	771
35·45	1n	,,	,,	773·4
34·67	1	,,	,,	778·2
34·50	1	,,	,,	779·2
34·15	1n	,,	,,	781·3
33·93	1	,,	,,	782·7
33·58	1	,,	,,	784·8
32·6	1b	,,	,,	791
32·00	1	,,	,,	794·6
31·50	1n	,,	,,	797·7
30·93	1	,,	,,	801·2
30·57	1	,,	,,	803·4
30·05	1n	,,	,,	806·6
29·90	1n	,,	,,	807·5
29·27	1n	,,	,,	811·4
28·55	1n	,,	,,	815·8
28·37	1	,,	,,	816.9
27·97	1	,,	,,	819·7
27·58	1	,,	,,	822·1
27·18	1	,,	,,	824·5
26·19	2	,,	,,	830·8
25·60	1	,,	,,	834·0
25·22	1	,,	,,	836·4
24·9	1n	,,	,,	838
24·45	1	,,	,,	841·1
24·33	1n	,,	,,	841·8
23·76	1n	,,	,,	845·4
23·40	1	,,	,,	847 6
23·05	1n	,,	,,	849·8
22·95	1n	,,	,,	850·4
22·2	1n	,,	,,	855
22·0	1n	,,	,,	856
21·65	1n	,,	,,	858·4
21·35	1n	,,	,,	860·3
21·17	1	,,	,,	861·4
20.35	1d	,,	,,	866·5
19·39	1	,,	,,	872·4
19·13	1	,,	,,	874·0
18·65	1	,,	,,	877·0
18·43	1	,,	,,	878·8
17·88	2	,,	,,	881·7
17·65	1	,,	,,	883·2
17·40	1	,,	,,	884·7

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4017·02	1d	1·11	7·0	24887·0
16·52	1	,,	,,	890·1
16·22	1	,,	,,	892·0
15·55	1	1·10	,,	896·1
15·43	1	,,	,,	896·9
14·99	1	,,	,,	899·8
14·72	1	,,	,,	901·4
14·35	1	,,	,,	903·7
13·6	1n	,,	,,	908
13·30	1	,,	,,	910·1
12·93	1	,,	,,	912·4
12·60	1	,,	,,	914·5
12·38	1	,,	,,	915·9
12·03	1	,,	,,	918·0
11·93	1	,,	,,	918·7
11·64	1d	,,	,,	920·5
11·20	1	,,	,,	923·2
11·00	1	,,	,,	924·4
10·88	1	,,	,,	925·1
10·53	1	,,	,,	927·3
09·73	1	,,	,,	932·3
09·60	1	,,	,,	933·1
09·37	1	,,	,,	934·5
09·25	1	,,	,,	935·3
08·89	1	,,	,,	937·6
08·59	1	,,	,,	939·4
08·22	1n	,,	,,	941·7
08·10	1	,,	,,	942·5
07·86	1	,,	,,	944·0
07·60	1	,,	,,	943·6
07·28	1	,,	,,	945·6
07·13	1	,,	,,	946·6
06·5	1b	,,	,,	952
05·92	1	,,	,,	956·0
05·83	1	,,	,,	956·6
05·40	1	,,	,,	959·3
05·00	1	,,	,,	961·8
04·80	1	,,	,,	963·0
04·70	1	,,	,,	963·7
04·30	1	,,	,,	966·1
04·20	1	,,	,,	966·8
03·95	1	,,	,,	968·3
03·58	1	,,	,,	970·6
03·32	1	,,	,,	972·2
02·51	2	,,	,,	977·3
02·14	1	,,	,,	979·7
01·82	1	,,	,,	981·5
01·40	1	,,	,,	984·1
01·08	1	,,	,,	986·2
00·87	1	,,	,,	987·5
00·47	1	,,	,,	990·0
00·13	1	,,	,,	992·2
3999·70	1	,,	,,	994·8
99·33	1n	,,	,,	997·6
98·95	1n	,,	,,	999·7

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3998·36	2	1·10	7·0	24993·4
97·49	1	,,	,,	998·8
97·26	1	,,	,,	25000·2
96·90	1	,,	,,	012·3
96·1	1b	,,	,,	017·5
95·67	1	,,	,,	020·2
95·17	2	,,	,,	023·3
94·42	1	,,	,,	028·0
94·0	1n	,,	,,	030·5
93·2	1n	,,	,,	035·5
92·70	2	,,	,,	038·6
92·35	1n	,,	,,	040·8
91·9	1n	,,	,,	044
91·75	1n	,,	,,	044·6
90·61	1	,,	,,	051·7
90·24	1	,,	,,	054·0
90·10	1	,,	,,	055·5
89·47	1n	,,	,,	059·2
89·02	1	,,	,,	061·2
88·78	1	,,	,,	063·8
88·50	1	,,	,,	065·0
88·18	1	,,	,,	067·0
86·87	1	,,	,,	069·0
87·19	1	,,	,,	073·2
87·03	1	,,	,,	074·2
86·60	1n	,,	,,	076·9
85·95	2	,,	,,	081·0
85·19	1	,,	,,	085·8
84·90	1	,,	,,	087·6
84·70	1	,,	,,	088·9
84·33	1	,,	,,	091·2
84·03	1	,,	,,	093·1
83·45	1n	,,	,,	096·7
83·1	1n	,,	,,	099
82·69	1	,,	,,	092·6
82·27	1	,,	,,	095·1
81·93	1	,,	,,	097·3
81·71	1	,,	,,	098·7
81·06	1	,,	,,	111·8
80·95	1	,,	,,	112·5
79·92	1	,,	7·1	119·0
79·67	1	,,	,,	120·6
79·27	1	,,	,,	123·1
78·95	1	,,	,,	125·1
78·4	1b	,,	,,	129
77·50	1	,,	,,	134·3
77·22	1	,,	,,	136·1
76·6	1b	,,	,,	140
75·4	1n	1·09	,,	148
75·13	1	,,	,,	149·0
74·70	1n	,,	,,	152·0
74·50	1n	,,	,,	153·3
74·15	1	,,	,,	155·5
73·40	1	,,	,,	160·3
72·51	1	,,	,,	165·9

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3971·58	1	1·09	7·1	25171·8
71·3	1n	,,	,,	174
70·75	1	,,	,,	177·0
70·60	1	,,	,,	178·0
70·30	1	,,	,,	179·9
69·55	1	,,	,,	184·6
69·23	1	,,	,,	189·2
68·63	2Ca	,,	,,	190·5
68·16	1	,,	,,	193·5
67·8	1n	,,	,,	196
67·6	1n	,,	,,	197
67·25	1n	,,	,,	199·3
66·73	2	,,	,,	202·5
66·5	1n	,,	,,	204
66·10	1	,,	,,	206·6
66·00	1	,,	,,	207·2
65·43	1	,,	,,	210·8
65·15	1	,,	,,	212·6
64·85	1	,,	,,	214·5
64·32	1	,,	,,	217·9
63·13	1	,,	,,	225·6
62·95	1	,,	,,	226·7
62·60	1	,,	,,	228·9
62·43	1	,,	,,	230·0
62·18	1	,,	,,	231·6
61·88	1n	,,	,,	235·7
61·70	1n	,,	,,	234·6
61·29	1	,,	,,	237·2
61·00	1	,,	,,	239·0
60·70	1	,,	,,	241·0
60·4	1n	,,	,,	243
59·9	1b	,,	,,	246
59·5	1b	,,	,,	249
58·3	1b	,,	,,	256
57·97	1	,,	,,	258·4
57·65	1	,,	,,	260·4
57·50	1	,,	,,	261·4
57·08	1	,,	,,	264·1
56·72	1	,,	,,	266·3
56·45	1n	,,	,,	268·0
56·2	1n	,,	7·2	270
55·91	1	,,	,,	271·5
55·55	1	,,	,,	273·7
54·87	2	,,	,,	278·1
54·40	1	,,	,,	281·1
53·75	1	,,	,,	285·2
53·13	1	,,	,,	285·9
52·67	1n	,,	,,	289·0
52·45	1	,,	,,	293·6
52·03	1n	,,	,,	296·2
51·75	1n	,,	,,	298·8
50·90	1	,,	,,	303·5
50·27	1	,,	,,	307·5
49·69	1	,,	,,	311·2
49·44	1	,,	,,	312·8

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3949·20	1	1·09	7·2	25314·4
48·54	1	,,	,,	318·5
48·13	1	,,	,,	321·2
47·05	1n	,,	,,	328·2
46·88	1	,,	,,	329·3
46·40	1	,,	,,	332·3
45·88	1n	,,	,,	335·1
45·45	1	,,	,,	338·5
45·10	1	,,	,,	340·8
44·77	1	,,	,,	342·9
44·32	2	,,	,,	345·8
43·97	1	,,	,,	348·1
43·68	1	,,	,,	350·0
43·00	1	,,	,,	354·2
42·71	1	,,	,,	356·1
42·43	1	,,	,,	357·9
42·22	1	,,	,,	359·2
41·60	1	,,	,,	363·2
41·26	1	,,	,,	365·4
40·80	1	,,	,,	367·4
40·64	1	,,	,,	368·4
40·45	1	,,	,,	369·6
39·93	1	,,	,,	378·0
39·56	1	,,	,,	380·4
39·27	1n	,,	,,	382·2
38·57	1n	,,	,,	382·7
38·00	1n	,,	,,	386·4
37·23	1	,,	,,	391·3
36·88	1	1·08	,,	393·6
36·55	1d	,,	,,	395·7
36·18	1	,,	,,	398·1
35·52	2	,,	,,	402·4
34·9	1n	,,	,,	406
33·92	1	,,	,,	412·8
33·81	4Ca	,,	,,	413·5
33·18	1	,,	,,	417·6
32·20	3	,,	,,	424·0
31·65	1	,,	,,	427·6
31·37	1n	,,	,,	429·2
31·15	2	,,	,,	430·6
31·0	1n	,,	,,	432
30·58	1	,,	,,	434·3
30·22	1	,,	,,	436·6
29·90	1	,,	,,	438·7
29·38	1	,,	,,	442·1
29·22	1	,,	,,	443·2
28·95	1	,,	,,	444·9
28·60	1	,,	,,	447·2
28·45	1	,,	,,	448·5
28·20	1	,,	,,	449·8
27·92	1	,,	,,	451·6
27·10	1	,,	,,	456·9
26·90	1	,,	,,	458·1
26·45	1n	,,	,,	461·1
25·7	1n	,,	,,	466

URANIUM—*continued*.

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3925·45	1n	1·08	7·2	25467·6
25·17	1n	,,	,,	469·4
25·0	1n	,,	,,	470·5
24·67	1	,,	,,	472·7
24·45	1	,,	,,	474·1
24·11	1	,,	,,	476·3
23·8	1n	,,	,,	478
23·5	1n	,,	,,	480
23·25	1	,,	,,	481·8
22·60	1	,,	,,	486·1
22·35	1	,,	,,	487·7
22·18	1	,,	,,	488·8
21·74	1	,,	,,	491·7
21·40	1	,,	,,	493·9
21·2	1n	,,	,,	495
20·07	1n	,,	,,	498·4
20·05	1n	,,	,,	499·7
19·95	1n	,,	,,	503·3
19·49	1	,,	,,	506·3
19·22	1	,,	,,	508·0
18·57	1	,,	,,	512·3
18·27	1	,,	,,	514·3
17·96	1	,,	,,	516·3
17·78	1	,,	,,	517·5
17·55	1	,,	,,	518·9
17·45	1	,,	,,	519·6
17·18	1	,,	,,	521·4
16·75	1n	,,	,,	524·2
16·60	1n	,,	,,	525·1
16·05	2	,,	,,	528·8
15·5	1n	,,	,,	532
15·20	1	,,	,,	534·3
14·94	1	,,	,,	536·0
14·45	3	,,	,,	539·2
14·0	1n	,,	,,	542
13·63	1	,,	,,	544·5
13·48	1	,,	,,	545·5
12·95	1n	,,	,,	549·0
12·60	1	,,	7·3	551·1
11·90	1	,,	,,	555·7
11·45	1n	,,	,,	558·8
11·15	1n	,,	,,	560·7
10·67	1	,,	,,	563·9
10·37	1	,,	,,	566·8
09·88	1	,,	,,	568·9
09·22	1	,,	,,	573·2
09·10	1	,,	,,	574·0
08·60	1n	,,	,,	577·3
08·01	1	,,	,,	581·2
07·72	1	,,	,,	583·1
07·42	1	,,	,,	585·1
07·17	1	,,	,,	586·8
06·7	2b	,,	,,	590
06·1	1b	,,	,,	594
05 00	1	,,	,,	600·9

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3904·73	1	1·08	7·3	25602·8
04·44	1	,,	,,	604·6
04·06	1	,,	,,	607·2
03·47	1	,,	,,	611·0
03·13	1	,,	,,	613·2
02·70	1	,,	,,	618·6
01·75	1n	,,	,,	622·3
00·48	1	,,	,,	630·6
3899·98	2	,,	,,	633·9
99·64	1	,,	,,	636·1
99·24	1n	,,	,,	638·7
98·97	1n	,,	,,	640·5
98·1	1n	,,	,,	646
97·87	1	,,	,,	648·7
97·44	1	,,	,,	650·6
97·22	1	,,	,,	652·0
96·92	2	1·07	,,	654·0
96·27	1	,,	,,	658·3
96·07	1	,,	,,	659·6
95·82*	1	,,	,,	661·2
95·41	1	,,	,,	663·9
95·20	1	,,	,,	665·3
94·89	1	,,	,,	667·4
94·26	1	,,	,,	671·5
93·96	1	,,	,,	673·5
93·48	1	,,	,,	676·7
92·85	2	,,	,,	680·8
92·56	1	,,	,,	682·7
92·22*	1	,,	,,	685 0
91·93	1	,,	,,	686·9
91·22	1	,	,,	691·6
90·51	3	,,	,,	696·3
89·54	1	,,	,,	702·7
88·72	1	,,	,,	708·1
88·32	1	,,	,,	710·8
87·85	1	,,	,,	713·8
87·36	1	,,	,,	717·2
86·6	1b	,,	,,	722
85·83	1	,,	,,	727·3
85·12	1	,,	,,	731·9
84·83	2	,,	,,	733·8
84·47	1	,,	,,	736·2
84·09	1	,,	,,	738·7
83·4	1n	,,	,,	743
83·20	1	,,	,,	744·6
82·79	1	,,	,,	746·8
82·52	1	,,	,,	747·8
82·05	1	,,	,,	750·9
81·61	2	,,	,,	755·6
80·8	1n	,,	,,	761
79·88	1	,,	,,	766·9
79·73	1	,,	,,	767·9
79·12	1	,,	,,	761·9

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3878·23	2	1·07	7·3	25777·7
77·60	1n	,,	,,	781·9
77·50	1n	,,	,,	782·5
77·1	1n	,,	,,	785
76·75	1	,,	,,	787·4
76·48	1	,,	,,	784·2
76·28	1	,,	,,	790·5
75·66	1	,,	,,	794·8
75·15	1n	,,	,,	798·1
74·68	1	,,	,,	801·3
74·20	2	,,	,,	804·5
73·28	1	,,	,,	810·5
73·22	1	,,	,,	811·0
73·03	1	,,	,,	812·2
72·70	1	,,	,,	814·4
72·50	1	,,	,,	815·8
72·06	1	,,	,,	818·8
71·69	1	,,	,,	821·3
71·52	1	,,	,,	822·4
71·18	1	,,	,,	824·6
70·73	1	,,	,,	827·7
70·22	1	,,	,,	831·0
69·90	1	,,	,,	833·2
69·05	1	,,	,,	838·8
68·95	1	,,	,,	839·5
68·57	1	,,	,,	842·0
67·32	1	,,	,,	851·2
67·17	1	,,	,,	852·1
66·89	1	,,	,,	853·9
66·62	1	,,	,,	855·7
66·08	2	,,	,,	859·3
65·65	1 (Fe)	,,	,,	862·2
65·26	1	,,	,,	864·7
64·85	1n	,,	,,	866·9
64·65	1	,,	,,	868·4
64·48	1	,,	,,	869·5
64·24	1	,,	,,	871·1
63·90	1	,,	,,	873·3
63·57	1	,,	,,	875·5
63·25	1n	,,	,,	877·6
62·45	1n	,,	,,	882·9
61·9	1n	,,	,,	887
61·30	1	,,	,,	890·8
60·75	1n	,,	,,	894·4
59·75	3	,,	,,	901·1
59·16	1	,,	,,	905·0
58·8	1n	,,	,,	907·5
58·35	1n	,,	,,	911·2
57·8	1n	,,	,,	914
57·35	1n	,,	,,	917·2
56·94	1	1·06	,,	919·9
56·74	1	,,	,,	921·3
56·5	1n (Fe)	,,	,,	923
55·96	1	,,	,,	926·5
55·60	1	,,	,,	929·0

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3855·00	1	1·06	7·3	25933·0
54·80	2	,,	,,	934·4
54·42*	1	,,	,,	937·0
53·95	1	,,	,,	940·1
53·53	1d	,,	,,	942·9
53·16	1	,,	,,	945·5
52·86	1n	,,	,,	947·4
52·28	1n	,,	,,	951·3
52·0	1n	,,	,,	953
51·45	1	,,	,,	956·9
51·10	1	,,	,,	959·3
50·95	1n	,,	,,	960·3
50·5	1	,,	,,	963
49·87	1	,,	,,	967·6
49·6*	1n	,,	,,	969
48·9	1n	,,	,,	974
48·77	1	,,	,,	975·6
48·24	1	,,	,,	978·6
47·95	1n	,,	,,	980·6
47·25	1n	,,	,,	985·3
46·70	1	,,	,,	989·0
46·38	1	,,	,,	991·2
45·98	1	,,	,,	993·9
45·50	2	,,	,,	26997·1
45·27	1	,,	,,	998·6
44·85	1	,,	,,	991·5
44·33	1n	,,	,,	995·0
44·13	1	,,	,,	996·4
43·92	1	,,	,,	997·8
43·61	1	,,	,,	999·9
42·86	1	,,	,,	015·0
42·36	1	,,	,,	018·4
42·00	1	,,	,,	020·8
41·20	1d (Fe)	,,	,,	026·2
40·50	1	,,	,,	031·0
40·05	1	,,	,,	034·0
39·77	1	,,	,,	035·9
39·63	1	,,	,,	036·9
39·15	2	,,	,,	040·2
38·28	2	,,	,,	046·1
37·95	1	,,	,,	048·3
37·63	1	,,	,,	050·4
37·40	1	,,	,,	052·0
37·0	1n	,,	,,	055
36·6	1n	,,	,,	057
36·45	1n	,,	,,	058·3
36·05	1	,,	,,	061·2
35·25	1	,,	,,	066·6
34·94	1	,,	,,	068·7
34·72	1	,,	,,	070·2
33·90	1	,,	,,	075·8
33·16	1	,,	,,	080·8
32·75	1	,,	,,	083·6

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3832·07	1	1·06	7·3	26088·2
31·60	3	„	„	091·4
30·77	1	„	„	097·0
30·36	1	„	„	099·8
29·95	1	„	„	002·7
29·50*	1	„	„	105·8
29·20	1	„	„	107·8
28·92	1	„	„	109·3
28·22	1	„	„	114·5
27·93*	1	„	„	116·5
27·56	1	„	„	119·0
27·02	1	„	„	122·7
26·65	2	„	„	125·2
25·61	1	„	„	132·3
25·29	1	„	„	134·5
24·85	1	„	„	137·5
24·1	1n	„	„	143
23·62	1	„	„	146·0
23·26	1	„	„	148·4
23·10	1	„	„	149·5
22·71	1	„	„	152·2
22·56	1	„	„	153·2
22·14	1	„	„	156·1
21·38	1	„	„	161·2
21·15	1	„	„	162·8
19·46	1	„	„	174·4
19·19	1	„	„	176·3
18·86	1d	„	„	178·5
18·62	1	„	„	180·1
18·28	1	„	„	182·5
17·80	1	„	„	185·7
17·30	1	„	7·4	189·1
16·75	1	1·05	„	192·9
16·22	1	„	„	196·5
15·50	1	„	„	201·5
15·30	1	„	„	202·9
14·96	1	„	„	205·2
14·25	2	„	„	210·1
13·94	2	„	„	212·2
13·40	1	„	„	215·9
12·86	1	„	„	219·6
12·72	1	„	„	220·6
12·42	1	„	„	222·7
12·16	1	„	„	224·4
11·81	1	„	„	226·8
11·67	1	„	„	227·8
11·20	1	„	„	231·1
11·05	1	„	„	232·1
10·33	1	„	„	237·0
09·73	1n	„	„	241·2
09·36	1	„	„	243·7
09·12	1	„	„	245·4
08·35	1n	„	„	250·7

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3807·75	1	1·05	7·4	26254·8
07·4	1b	"	"	257
06·5	1n	"	"	263
06·40	1	"	"	264·1
05·99	1	"	"	267·0
05·83	1	"	"	275·0
05·20	1n	"	"	272·4
05·00	1	"	"	273·8
04·52	1n	"	"	277·1
04·1	1b	"	"	280
03·50	1	"	"	284·2
03·25	1	"	"	285·9
03·00	1	"	"	287·6
02·43	1	"	"	291·6
02·10	1	"	"	293·9
01·90	1n	"	"	295·2
01·45	1	"	"	298·4
01·35	1	"	"	299·0
00·9	1n	"	"	303
00·43	1n	"	"	305·4
00·30	1n	"	"	306·3
3799·75	1	"	"	310·1
99·36	1	"	"	312·8
98·99	1	"	"	324·9
98·40	1	"	"	319·4
97·93	1d	"	"	322·8
97·70	1	"	"	324·3
97·2	1b	"	"	328
96·98	1	"	"	329·4
96·70	1	"	"	331·3
96·62	1	"	"	331·8
96·38	1	"	"	333·5
96·20	1	"	"	334·7
95·76	1	"	"	337·8
95·29	1	"	"	341·1
94·50	1	"	"	346·5
94·15	1	"	"	349·0
93·74	1	"	"	351·8
93·45	1	"	"	353·8
93·24	2	"	"	355·2
92·69	1	"	"	359·1
92·50	1d	"	"	360·4
92·03	1	"	"	363·7
91·50	1	"	"	367·4
91·25	1	"	"	369·1
90·94	1	"	"	371·3
90·50	1	"	"	374·3
90·36	1	"	"	375·3
90·03	1	"	"	377·6
89·76	1	"	"	379·5
89·36	1	"	"	382·2
89·02	1	"	"	384·5
88·77	1	"	"	386·3
88·37	1	"	"	389·1
88·15	1	"	"	390·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3787·40	1	1·05	7·4	26395·9
86·99	1	,,	,,	398·8
86·74	1	,,	,,	400·5
86·30	1n	,,	,,	403·6
85·5	1n	,,	,,	409
85·30	1	,,	,,	410·6
84·90	1	,,	,,	413·4
84·02	1	,,	,,	419·5
83·80	1n	,,	,,	421·1
82·99	2	,,	,,	426·7
82·5	1b	,,	,,	430
82·1	1b	,,	,,	433
81·60	1	,,	,,	436·4
81·33	1	,,	,,	438·3
81·23	1	,,	,,	443·6
80·90	2	,,	,,	441·3
80·44	1	,,	,,	444·5
79·3	1n	,,	,,	453
79·18	1	,,	,,	453·4
78·75	1n	,,	,,	456·4
78·5	1n	,,	,,	459
78·15	1	,,	,,	460·6
77·83	1	,,	,,	462·9
77·61	1	,,	,,	464·5
77·50	1n	,,	,,	465·1
77·17	1	,,	,,	467·2
76·87	1	1·04	,,	469·3
76·63	1	,,	,,	471·0
76·15	1	,,	,,	474·3
75·74	1	,,	,,	476·9
75·65	1	,,	,,	477·9
75·42	1	,,	,,	479·5
75·02	1	,,	,,	482·3
74·57	1	,,	,,	485·5
74·22	1	,,	,,	488·0
73·82	1	,,	,,	491·0
73·72	1	,,	,,	493·7
73·57	1	,,	,,	492·7
72·97	2	,,	,,	496·9
72·50	1	,,	7·5	500·1
71·55	1	,,	,,	506·8
70·60	1	,,	,,	513·5
70·30	1	,,	,,	515·6
69·68	2	,,	,,	519·8
68·95	1	,,	,,	525·0
68·67	1	,,	,,	527·0
68·57	1	,,	,,	527·8
68·22	1n	,,	,,	530·1
68·02	1n	,,	,,	531·5
67·62	1	,,	,,	534·3
67·33*	1	,,	,,	536·4
67·05	1	,,	,,	538·5
66·6	1b	,,	,,	542

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3766·00	1	1·04	7·5	26545·9
65·47	1n	,,	,,	549·6
64·95	1n	,,	,,	553·2
64·71	1	,,	,,	555·0
64·30	1	,,	,,	557·9
64·00	1	,,	,,	560·0
63·43	1	,,	,,	564·0
63·13	1	,,	,,	566·1
62·89	1	,,	,,	567·8
62·27	1	,,	,,	572·2
62·11	1	,,	,,	573·3
61·74	1	,,	,,	575·9
61·23	1	,,	,,	579·5
61·02	1	,,	,,	581·1
60·5	1n	,,	,,	585
60·00	1	,,	,,	588·2
59·38	2	,,	,,	592·6
58·2	1n	,,	,,	601
57·09	1	,,	,,	608·9
56·82	1n	,,	,,	610·8
55·7	1b	,,	,,	618
55·2	1b	,,	,,	622
54·46	1	,,	,,	627·5
54·12	1	,,	,,	629·8
53·85	1n	,,	,,	631·9
53·7	1n	,,	,,	633
53·22	1	,,	,,	636·2
53·02	1	,,	,,	637·7
52·84	1	,,	,,	639·0
52·49	1	,,	,,	644·4
52·30	1	,,	,,	642·9
51·92	1	,,	,,	645·6
51·46	1	,,	,,	648·8
51·3	1n	,,	,,	650
50·51	1	,,	,,	655·5
50·14	1	,,	,,	658·2
50·02	1	,,	,,	659·0
49·35	1	,,	,,	663·8
48·90	2	,,	,,	667·0
47·34	2	,,	,,	668·7
46·82	1n	,,	,,	678·2
46·60	2	,,	,,	683·3
46·10	1n	,,	,,	686·9
45·75	1	,,	,,	689·3
45·53	1	,,	,,	690·8
45·15	1	,,	,,	693·7
44·95	1	,,	,,	695·1
44·65	1	,,	,,	697·2
44·39	1	,,	,,	699·0
43·97	1d	,,	,,	702·1
43·55	1	,,	,,	704·9
43·07	1n	,,	,,	708·6
42·96	1	,,	,,	709·3
42·67	1n	,,	,,	711·5
42·50	1	,,	,,	712·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3741·87	1	1·04	7·5	26717·0
41·56	1	,,	,,	719·3
41·43	1	,,	,,	720·2
41·12	1	,,	,,	722·4
40·85	1n	,,	,,	724·3
40·4	1b	,,	,,	728
39·50	1	,,	,,	734·0
39·18	1	,,	,,	735·3
38·80	1	,,	,,	738·0
38·48	1	,,	,,	740·2
38·23	2	,,	,,	742·0
37·45	2n	1·03	,,	747·5
36·75	1n	,,	,,	753·7
36·2	1n	,,	,,	758
35·7	1n	,,	,,	761
35·05*	1	,,	,,	766·6
34·83	1	,,	,,	767·4
33·95	1	,,	,,	773·7
33·75	1	,,	,,	775·2
33·25	2	,,	,,	778·7
32·77	2	,,	,,	782·2
32·43	1	,,	,,	784·6
31·9	1n	,,	,,	788·5
31·64	1	,,	,,	790·4
31·10	1	,,	,,	794·3
30·98	1	,,	,,	795·1
30·37	1	,,	,,	799·5
30·00	2	,,	,,	802·1
29·49	1	,,	,,	805·6
29·00	1	,,	,,	809·3
28·60	1	,,	,,	812·2
28·01	1	,,	7·6	816·5
27·91	1	,,	,,	817·1
27·30	1	,,	,,	821·5
27·02	1	,,	,,	823·5
26·72	1	,,	,,	828·7
26·49	1	,,	,,	827·3
26·22	1	,,	,,	829·2
25·93	1n	,,	,,	831·3
25·80	1	,,	,,	832·2
25·55	1	,,	,,	834·0
25·26	1	,,	,,	836·1
25·18	1	,,	,,	836·6
24·50	1	,,	,,	841·6
24·35	1	,,	,,	842·5
23·85	2n	,,	,,	846·2
22·92	1	,,	,,	853·0
22·6	1n	,,	,,	855
21·95	1n	,,	,,	866·0
21·55	1n	,,	,,	862·9
20·54	1	,,	,,	870·1
20·13*	1	,,	,,	873·2
19·75	1	,,	,,	875·9

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3719·50	1	1·03	7·6	26877·7
18·98	1n	,,	,,	881·5
18·78	1	,,	,,	882·9
18·25	2	,,	,,	886·8
17·60	1	,,	,,	891·5
17·23	1	,,	,,	893·2
16·95	1	,,	,,	895·2
16·72	1	,,	,,	896·9
16·32	1	,,	,,	899·8
15·85	1	,,	,,	904·1
15·63	1	,,	,,	905·7
15·15	1	,,	,,	909·2
14·93	1	,,	,,	910·8
14·60	1	,,	,,	913·2
14·40	1	,,	,,	914·6
13·95	1	,,	,,	917·9
13·82	1	,,	,,	918·7
12·4	1b	,,	,,	929
11·98	1	,,	,,	932·2
11·10	1	,,	,,	938·6
11·00	1	,,	,,	939·3
10·73	1	,,	,,	941 2
10·36	1	,,	,,	948·4
10·05	1	,,	,,	946·2
09·65	1n	,,	,,	949·1
09·45	1n	,,	,,	950·5
09·2	1n	,,	,,	952
08·75	1n	,,	,,	955·7
08·10	1	,,	,,	960·4
07·80	1	,,	,,	962·5
07·45	1n	,,	,,	965·0
06·86	1	,,	,,	969·4
06·10	2	,,	,,	974·9
05·72	2	,,	,,	977·7
05·20	1	,,	,,	981·5
04·50	1	,,	,,	986·6
04·25	1	,,	,,	988·4
03·80	1	,,	,,	991·7
03·45	1	,,	,,	994·2
02·80	1	,,	,,	999·0
02·38	1n	,,	,,	27002·1
01·9	1n	,,	,,	006
01·68	2	,,	,,	007·3
00·74	1	,,	,,	014·1
00·00	1	,,	,,	019·4
3699·83	1	,,	,,	020·6
99·60	1	,,	,,	022·3
98·63	1d	,,	,,	029·4
98·10	1	,,	,,	033·3
97·69	1	1·02	,,	036·4
97·32	1	,,	,,	039·1
96·98	1	,,	,,	041·5
96·48	1	,,	,,	045·2
96·25	1	,,	,,	046·9
95·98	1	,,	,,	048·8

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3695·35	1n	1·02	7·6	27053·4
94·95	1n	,,	,,	056·3
94·46	1	,,	,,	060·0
93·89	2	,,	,,	064·1
93·46	1	,,	,,	067·3
93·08	1n	,,	,,	070·1
92·48	1	,,	,,	074·4
92·15	1	,,	,,	079·6
92·07	1	,,	,,	077·5
91·65	1n	,,	,,	080·5
91·15	1n	,,	,,	081·6
91·00	1n	,,	,,	085·3
90·43	1	,,	,,	084·2
90·18	1	,,	,,	091·3
89·80	1	,,	,,	094·1
89·37	1	,,	,,	097·2
89·19	1	,,	,,	098·6
88·93	1	,,	,,	100·5
88·53	1	,,	,,	103·5
88·02	1	,,	,,	107·2
87·88	1	,,	,,	108·2
87·55	1	,,	,,	110·6
87·27	1	,,	,,	112·7
87·12	1	,,	,,	113·8
86·93	1	,,	,,	115·7
86·63	1	,,	,,	117·4
85·94	1	,,	,,	122·5
85·71	1	,,	,,	124·2
85·45	1	,,	,,	126·1
84·77	1n	,,	,,	131·1
84·45	1	,,	,,	133·4
84·30	1	,,	,,	134·6
83·75	1	,,	7·7	138·6
83·00	1	,,	,,	144·1
82·63	1	,,	,,	146·8
82·25	2	,,	,,	149·6
81·85	1	,,	,,	152·6
81·07	1d	,,	,,	158·3
80·68	1	,,	,,	161·2
80·45	1	,,	,,	162·9
80·10	1	,,	,,	165·5
79·99	1	,,	,,	166·3
79·54	1	,,	,,	169·6
78·93	2	,,	,,	174·1
78·3	1n	,,	,,	179
77·82	1	,,	,,	182·3
77·60	1	,,	,,	184·0
77·2	1n	,,	,,	187
76·75	2d	,,	,,	190·2
75·75	1d	,,	,,	197·6
75·26	1	,,	,,	201·3
75·19	1	,,	,,	201·8
74·90	1	,,	,,	203·9
74·25	1	,,	,,	208·7
73·56	1	,,	,,	213·8

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3673·22	1	1·02	7·7	27216·3
72·75	2	,,	,,	219·8
71·98	1n	,,	,,	225·5
71·75*	1n	,,	,,	227·2
70·7	1n	,,	,,	235
70·40	1	,,	,,	237 3
70·26	3	,,	,,	238·3
69·50	1	,,	,,	244·0
69·33	1	,,	,,	245·2
68·90	1	,,	,,	248·4
68·25	1n	,,	,,	253·2
68·13	1	,,	,,	254·1
67·9	1n	,,	,,	256
67·30	1	,,	,,	260·3
66·95	1d	,,	,,	206·3
66·35	1	,,	,,	207·5
66·28	1	,,	,,	268·0
65·6	1n	,,	,,	273
65·3	1n	,,	,,	275
64·92	1	,,	,,	278·0
64·69	1	,,	,,	279·7
64·40	1	,,	,,	283·9
64·0	1n	,,	,,	285
63·5	1n	,,	,,	289
63·2	1n	,,	,,	291
62·8	1n	,,	,,	294
62·50	1	,,	,,	296·1
62·10	1	,,	,,	299·0
61·60	1	,,	,,	302·8
61·47	1	,,	,,	304·4
60·90	1n	,,	,,	308·0
60·5	1n	,,	,,	311
60·27	1	,,	,,	313·3
59·76	1	,,	,,	317·1
59·28	1	,,	,,	320·7
59·19	1	,,	,,	321·3
58·8	1n	,,	,,	324
58·30	1	,,	,,	327·4
58·01	1	,,	,,	329·6
57·50	2	1·01	,,	333·3
57·09	1	,,	,,	336·4
56·80	1	,,	,,	338·6
56·40	1	,,	,,	341·6
56·30	1	,,	,,	342·4
56·09	1	,,	,,	344·0
55·61	1	,,	,,	347·5
55·35	1	,,	,,	349·5
55·05	1	,,	,,	351·7
54·80	1	,,	,,	353·6
54·43	1	,,	,,	356·3
54·25	1	,,	,,	357·7
53·65	1	,,	,,	362·2
53·34	1	,,	,,	364·5

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3652·21	1	1·01	7·7	27373·0
51·6	1b	,,	,,	378
50·8	1b	,,	,,	384
50·55	1n	,,	,,	385·4
50·16	1	,,	,,	388·4
49·83	1	,,	,,	390·8
49·53	1	,,	,,	393·1
49·02	1	,,	,,	396·9
48·65	1	,,	,,	399·7
48·27	1	,,	,,	402·6
47·9	1n	,,	,,	405
47·7	1n	,,	,,	407
47·00	1	,,	,,	412·1
46·63	1	,,	,,	414·9
46·13	1	,,	,,	418·6
45·82	1	,,	,,	421·0
45·60	1	,,	,,	422·6
45·19	1	,,	,,	425·7
44·93	1	,,	,,	427·7
44·38	1	,,	,,	431·8
43·75	1	,,	,,	436·6
43·2	1b	,,	,,	441
42·95	1	,,	,,	442·6
42·59	1	,,	,,	445·3
42·20	1	,,	,,	448·2
41·37	1	,,	,,	454·5
41·09	1	,,	,,	456·6
40·84	2	,,	,,	458·5
40·17	1	,,	,,	463·5
39·75*	1n	,,	,,	466·7
39·31	1	,,	7·8	469·9
38·79	1	,,	,,	473·9
38·33	1	,,	,,	477·3
38·03	1	,,	,,	479·6
37·63	1	,,	,,	482·6
36·7	1b	,,	,,	490
36·3	1b	,,	,,	493
35·74	1n	,,	,,	496·9
35·45	1	,,	,,	499·1
35·17	1	,,	,,	501·2
34·70	1	,,	,,	504·8
34·40	1n	,,	,,	507·1
33·42	2	,,	,,	514·5
33·05	1	,,	,,	517·3
32·9	1n	,,	,,	518
32·33	1	,,	,,	522·7
32·0	1n	,,	,,	525
30·84	3	,,	,,	534·0
30·40	1	,,	,,	537·4
30·17	1	,,	,,	539·1
29·70	1	,,	,,	542·7
29·25	1	,,	,,	546·1
28·96	1	,,	,,	548·3

* Pb?

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3628·51	1	1·01	7·8	27551·7
28·23	1	„	„	553·9
27·86	1	„	„	556·7
27·60	1	„	„	558·6
27·2	1n	„	„	562
26·95	1n	„	„	563·6
26·60	2r	„	„	566·2
25·65	1	„	„	573·5
25·25	1	„	„	576·5
25·00	1	„	„	578·4
24·75	1	„	„	580·3
24·42	1	„	„	582·8
24·00	1n	„	„	586·0
23·6	1n	„	„	589
23·21	2	„	„	592·0
22·83	1	„	„	594·9
22·45	1	„	„	597·8
22·25	1	„	„	599·4
22·00	1	„	„	601·3
21·72	1	„	„	603·4
21·65	1	„	„	603·9
21·20	1	„	„	607·3
21·03	1	„	„	608·7
20·68	1	„	„	611·3
20·31	2	„	„	614·1
19·95	1	„	„	616·9
19·56	1	„	„	619·9
19·32	1	„	„	621·7
18·94*	1	„	„	624·6
18·65	2	„	„	626·8
18·2	1b	„	„	630
17·72	1d	1·00	„	633·9
17·28	1	„	„	637·3
16·90	2	„	„	640·2
16·49	1	„	„	643·3
15·98	1	„	„	647·2
15·6	1n	„	„	650
15·42	1	„	„	651·5
15·15	1	„	„	653·6
14·85	1	„	„	655·9
14·4	1n	„	„	659
14·16	1n	„	„	661·1
13·95	1	„	„	662·8
13·55	1n	„	„	665·8
13·30	1	„	„	667·7
12·88	1	„	„	670·9
12·7	1	„	„	672
12·05	1	„	„	677·3
11·85	1	„	„	678·8
11·44	1	„	„	682·0
11·20	1	„	„	683·8
10·87	2	„	„	686·4
10·65	2	„	„	688·0

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3609·86	2	1·00	7 8	27694·1
09·53	1	,,	,,	696·6
09·13	1	,,	,,	699·7
08·84	1	,,	,,	701·9
08·55	1	,,	,,	704·2
08·20	1	,,	,,	706·9
07·97	1	,,	,,	708·6
07·18	1n	,,	,,	713·9
07·52	1	,,	,,	712·0
07·15	1	,,	,,	714·9
06·51	2	,,	,,	719·8
06·26	1	,,	,,	721·8
06·00	1	,,	,,	723·8
05·90	1	,,	,,	724·5
05·65	1	,,	,,	726·5
05·35	1	,,	,,	728·8
04·80	1	,,	,,	733·1
04·58	1	,,	,,	734·7
04·35	1	,,	,,	736·5
03·95	1	,,	,,	739·5
03·65	1	,,	,,	741·8
03·28	1	,,	,,	744·7
02·67	1	,,	,,	749·4
02·45	1n	,,	,,	751·1
01·6	1n	,,	,,	758
01·3	1b	,,	,,	760
00·9	1n	,,	,,	763
00·7	1n	,,	,,	765
00·02	2	,,	,,	769·8
3599·50	1	,,	,,	773·8
99·13	1	,,	,,	776·8
98·72	1	,,	,,	779·9
98·4	1n	,,	,,	782
98·25	1n	,,	,,	783·4
97·95	1	,,	,,	785·8
97·78	1	,,	,,	786·2
97·40	1	,,	,,	789·1
97·31	1	,,	,,	789·8
97·01	1	,,	,,	793·1
96·2	1n	,,	,,	799
95·69	1	,,	,,	803·4
95·14	2	,,	,,	807·6
94·25	1d	,,	,,	814·3
93·88	1	,,	7·9	817·1
93·68	1	,,	,,	818·1
93·40	1	,,	,,	820·9
92·92	1d	,,	,,	824·7
92·50	1	,,	,,	827·9
92·03	1	,,	,,	831·4
91·74	1	,,	,,	833·6
91·4	1n	,,	,,	836
90·71	1	,,	,,	841·9
90·48	1	,,	,,	843·6
90·1	1b	,,	,,	846·5
89·9	1b	,,	,,	848

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3589·3	1b	1·00	7·9	27853
88·5	1b	,,	,,	859
88·05	1n	,,	,,	862·4
87·70	1	,,	,,	865·1
87·2	1b	,,	,,	869
86·5	1b	,,	,,	874·5
86·02	1n	,,	,,	878·3
85·54	1	,,	,,	881·9
85·33	1	,,	,,	883·5
85·05	3	,,	,,	885·6
84·13	1	,,	,,	892·5
83·6	1n	,,	,,	897
83·4	1n	,,	,,	899
83·00	1	,,	,,	901·7
82·23	2	,,	,,	907·8
82·02	2	,,	,,	909·4
81·41	1	,,	,,	914·0
80·45	1n	,,	,,	921·2
80·30	1n	,,	,,	922·7
79·96	1	,,	,,	925·6
79·56	1	,,	,,	928·6
79·12	1	,,	,,	931·9
78·97	1n	,,	,,	933·0
78·53	1	,,	,,	936·3
78·1	1b	,,	,,	940
77·26	1	0·99	,,	946·7
77·05	1	,,	,,	948·3
76·78	1	,,	,,	950·3
76·41	2	,,	,,	953·1
75·97	1	,,	,,	956·4
75·64	1	,,	,,	958·9
74·98	1n	,,	,,	965·3
74·55	1	,,	,,	968·5
74·25	1	,,	,,	970·7
73·40	1	,,	,,	976·7
73·10	1	,,	,,	979·1
72·75	1n	,,	,,	982·0
72·55	1	,,	,,	983·6
72·27	1	,,	,,	985·7
71·85	1	,,	,,	988·8
71·42	1	,,	,,	992·0
71·19	1	,,	,,	993·8
70·80	1	,,	,,	997·6
70·34	1	,,	,,	28000·4
70·05	1	,,	,,	002·5
69·85	1	,,	,,	004·4
69·72	1	,,	,,	008·4
69·25	2	,,	,,	009·2
68·97	1	,,	,,	011·4
68·83	1	,,	,,	012·5
68·45	1	,,	,,	015·5
68·19	1	,,	,,	017·6
67·97	1	,,	,,	019·3
67·65	1	,,	,,	021·8
67·18	1	,,	,,	025·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3566·78	2	0·99	7·9	28029·6
66·55	1	,,	,,	030 2
65·93	2	,,	,,	035·1
65·56*	1	,,	,,	038·1
65·20	1n	,,	,,	040·9
65·07	1	,,	,,	041·9
64·78	1	,,	,,	044·2
64·40	1	,,	,,	047·3
64·1	1n	,,	,,	050
63·85	1	,,	,,	051·7
63·60	1	,,	,,	053·6
63·50	1	,,	,,	054·4
63·23	1	,,	,,	056·4
62·25	1n	,,	,,	064·2
61·95	2	,,	,,	066·6
61·62	1	,,	,,	069·2
61·24	1	,,	,,	072·2
60·65	1n	,,	,,	076·9
60·5	1n	,,	,,	078
60·10	1	,,	,,	081·2
59·21	1	,,	,,	088·2
58·71	1	,,	,,	092·2
58·22	1	,,	,,	096·0
58·00	1	,,	,,	097·8
57·75	1	,,	,,	099·8
57·49	1	,,	,,	101·8
57·15	1	,,	,,	104·5
56·75	1	,,	,,	107·6
56·43	1	,,	,,	110·1
56·05	1	,,	,,	118·7
55·70	1	,,	,,	115·9
55·52	1	,,	,,	117·3
55·00	1n	,,	,,	121·5
54·70	1n	,,	,,	123·9
54·43	1	,,	,,	126·0
54·00	1n	,,	,,	129·4
53·62	1n	,,	,,	132·4
53·1	1b	,,	,,	136
52·84	1	,,	,,	148·5
52·36	2	,,	,,	142·2
51·95	1n	,,	8·0	145·5
51·49	1	,,	,,	149·2
51·24	1	,,	,,	151·2
51·02	2	,,	,,	152·9
50·77	1	,,	,,	154·9
50·68	1	,,	,,	155·6
50·43	1	,,	,,	157·6
49·88	1n	,,	,,	161·9
49·36	1	,,	,,	166·1
48·95	1n	,,	,,	169·3
48·4	1b	,,	,,	174
47·96	1	,,	,,	177·2
47·70	1	,,	,,	179·3

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3547·36	2	0·99	8·0	28182·0
46·90	2	,,	,,	185·6
46·55	2	,,	,,	188·4
46·31	1	,,	,,	190·3
45·86	2	,,	,,	193·9
44·86	1	,,	,,	201·8
44·40	1	,,	,,	205·5
44·11	1	,,	,,	207·8
43·90	1	,,	,,	209·5
43·58	1	,,	,,	212·1
43·35	1	,,	,,	213·9
42·9	1n	,,	,,	217·5
42·5	1n	,,	,,	221
42·06	1	,,	,,	224·0
41·45	1	,,	,,	228·9
41·15	1	,,	,,	231·4
40·82	1	,,	,,	234·0
40·64	2	,,	,,	235·5
39·81	1	,,	,,	242·1
39·60	1	,,	,,	243·8
39·40	1	,,	,,	245·4
39·10	1	,,	,,	247·8
38·81	1	,,	,,	250·1
38·57	1	,,	,,	252·0
38·35	1	,,	,,	253·8
38·00	1	0·98	,,	256·6
37·60	1	,,	,,	259·8
37·23	1	,,	,,	262·8
36·95	1	,,	,,	265·1
36·52	1	,,	,,	268·3
36·25	1n	,,	,,	270·5
36·0	1b	,,	,,	272
35·8	1b	,,	,,	274
35·3	1b	,,	,,	278
35·1	1b	,,	,,	280
34·50	1	,,	,,	284·5
34·23	1	,,	,,	286·8
33·75	2	,,	,,	290·5
33·18	1	,,	,,	295·1
32·97	1	,,	,,	296·8
32·80	1	,,	,,	298·2
32·3	1n	,,	,,	302
31·85	1	,,	,,	305·7
31·29	2	,,	,,	310·3
31·1	1n	,,	,,	312
30·30	1	,,	,,	318·2
29·95	1n	,,	,,	320·9
29·75	1	,,	,,	322·5
29·35	1	,,	,,	325·7
29·26	1	,,	,,	326·6
28·87	2	,,	,,	329·6
28·50	1	,,	,,	332·6
28·20	1d	,,	,,	335·1
27·78	1	,,	,,	338·5
27·00	1	,,	,,	344·7

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3526·74	1	0·98	8·0	28346·8
26·25	1	,,	,,	350·7
25·98	1	,,	,,	352·9
25·88	1	,,	,,	353·7
25·35	1	,,	,,	358·0
24·93	1	,,	,,	361·4
24·62	1	,,	,,	363·8
23·77	2	,,	,,	370·7
23·52	1	,,	,,	372·7
22·9	1b	,,	,,	378
22·72	1n	,,	,,	379·2
22·22	1	,,	,,	383·2
21·67	1	,,	,,	387·6
20·98	2	,,	,,	393·2
20 15	2	,,	,,	399·8
19·91	1	,,	,,	401·7
19·55	1n	,,	,,	404·6
19·16	1	,,	,,	407·8
18·92	1	,,	,,	409·8
18·69	1	,,	,,	411·6
17·84	1	,,	,,	418·4
17·62	1	,,	,,	420·3
17·40	1	,,	,,	422·1
17·23	1	,,	,,	423·5
17·03	1	,,	,,	425·1
16·65	1	,,	,,	428·2
15·56	1	,,	,,	437·0
15·43	1	,,	,,	438·1
15·10	1	,,	,,	440·7
14·83	1	,,	,,	442·9
14·65	1n	,,	,,	444·3
13·85	1n	,,	,,	450·8
13·56	1	,,	,,	453·2
13·25	1	,,	,,	455·7
12·86	1	,,	,,	458·9
12·64	1	,,	,,	460·7
12·40	1	,,	,,	462·6
12·06	1	,,	,,	465·3
11·80	1	,,	,,	467·7
11·65	1	,,	,,	468·8
11·20	1n	,,	,,	472·3
11·03	1	,,	,,	473·7
10·65	1nd	,,	,,	476·7
10·25	1	,,	,,	480·0
09.85	2	,,	,,	483·2
09·52	1	,,	,,	485·8
09·25	1	,,	8·1	488·0
09·21	1	,,	,,	488·3
08·49	1n	,,	,,	494·1
07·9	1n	,,	,,	499
07·47	1	,,	,,	402·5
07·22	1	,,	,,	404·5
06·95	1	,,	,,	406·7
06·75	1	,,	,,	508·3
06·50	1		,,	510·4

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3505·65	1n	0·98	8·1	28517·3
05·28	1	,,	,,	520·3
05·20	1	,,	,,	520·9
04·85	1	,,	,,	523·7
04·62	1	,,	,,	525·6
04·17	1n	,,	,,	529·2
03·97	1n	,,	,,	531·0
03·50	1n	,,	,,	534·8
03·16	1n	,,	,,	537·5
02·79	1	,,	,,	540·4
02·48	1n	,,	,,	543·0
01·9	1b	,,	,,	548
01·47	1	,,	,,	551·4
01·15	1nd	,,	,,	554·0
00·65	1	,,	,,	558·2
00·55	1	,,	,,	559·8
00·27	1	,,	,,	561·3
3499·98	1	,,	,,	563·5
99·53	1	,,	,,	567·2
99·25	1	,,	,,	569·5
98·90	1	0·97	,,	572·3
98·78	1	,,	,,	573·4
98·57	1	,,	,,	575·1
98·37	1	,,	,,	576·8
97·81	1	,,	,,	581·1
97·45	1	,,	,,	584·1
97·23	1	,,	,,	585·9
97·05	1	,,	,,	587·4
96·7	1n	,,	,,	590
96·57	1	,,	,,	591·4
96·13	1	,,	,,	595·0
95·87	1	,,	,,	597·2
95·04	2	,,	,,	604·1
94·19	1	,,	,,	610·6
93·87	1	,,	,,	613·3
93·52	2	,,	,,	616·2
92·97	1	,,	,,	620·8
92·4	1b	,,	,,	625·5
92·0	1b	,,	,,	629
91·55	1	,,	,,	632·5
90·97	1	,,	,,	637·3
90·77	1	,,	,,	639·0
90·43	2	,,	,,	641·6
89·75	2	,,	,,	647·2
89·53	1	,,	,,	649·0
89·00	1	,,	,,	653·4
88·35	1n	,,	,,	658·8
87·75	1n	,,	,,	663·7
87·25	1n	,,	,,	667·9
87·07	1n	,,	,,	669·2
86·47	1	,,	,,	674·1
86·16	1	,,	,,	676·7
85·45	1	,,	,,	682·6
85·10	1	,,	,,	685·5
84·71	1	,,	,,	688·7

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3484·48	1	0·97	8·1	28690·1
83·98	1	,,	,,	694·7
83·73	1n	,,	,,	696·8
83·30	1	,,	,,	700·3
82·67	2	,,	,,	705·5
82·40	1	,,	,,	707·7
81·9	1b	,,	,,	712
81·3	1b	,,	,,	717
80·49	2	,,	,,	723·4
79·99	1	,,	,,	727·6
79·40	1	,,	,,	732·5
78·47	1	,,	,,	740·1
78·01	1	,,	,,	744·0
77·68	1	,,	,,	746·6
77·26	1	,,	,,	750·1
76·65	1	,,	,,	755·2
76·30	1	,,	,,	758·1
76·08	1	,,	,,	759·9
75·88	1	,,	,,	761·6
75·18	1	,,	,,	767·4
74·75	2	,,	,,	770·0
74·35	1	,,	,,	774·3
73·90	1n	,,	,,	778·0
73·57	1n	,,	,,	780·7
73·19	1	,,	,,	783·9
73·00	1	,,	,,	785·5
72·73	1	,,	,,	787·7
72·67	1	,,	,,	788·2
72·25	1	,,	,,	791·7
71·90	1	,,	,,	794·6
71·26	1	,,	,,	799·9
70·8	1n	,,	8·2	804
70·47	1	,,	,,	808·8
69·96	1	,,	,,	810·5
69·7	1b	,,	,,	813
69·38	1	,,	,,	815·4
69·28	1	,,	,,	816·2
68·70	1n	,,	,,	821·0
68·26	1n	,,	,,	824·7
67·85	1n	,,	,,	828·1
67·3	1b	,,	,,	833
66·80	1	,,	,,	837·8
66·50	1	,,	,,	839·3
66·05	1n	,,	,,	843·2
65·6	1nd	,,	,,	847
65·12	1	,,	,,	850·8
64·82	1	,,	,,	853·3
64·41	1	,,	,,	856·7
63·82	2	,,	,,	861·6
63·50	1	,,	,,	864·3
62·87	1n	,,	,,	869·5
62·40	1	,,	,,	873·5
62·17	1	,,	,,	875·4
61·65	1n	,,	,,	879·8
61·19	1	,,	,,	883·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3461·00	1	0·97	8·2	28885·2
60·64	1	,,	,,	888·2
60 55	1	,,	,,	888·9
60·10	1	,,	,,	892·7
59·88	1	,,	,,	894·6
59·5	1n	,,	,,	898
59·3	1n	,,	,,	899
59·1	1b	,,	,,	901
58·85	1	0·96	,,	903·3
58·37	1	,,	,,	907·4
57·89	2	,,	,,	911·6
57·24	2	,,	,,	916·4
56·74	1	,,	,,	920·7
56·50	1	,,	,,	922·8
56·1	1n	,,	,,	926
55·91	1	,,	,,	927·9
55·57	1	,,	,,	930·9
55·00	1	,,	,,	935·4
54·80	1n	,,	,,	937·0
54·40	1n	,,	,,	940·4
54·26	1	,,	,,	941·2
53·98	1	,,	,,	943·8
53·72	2	,,	,,	945·9
53·1	1n	,,	,,	951
52·92	1n	,,	,,	952·8
52·63	1n	,,	,,	955·4
52·52	1n	,,	,,	956·3
52·1	1b	,,	,,	960
51·8	1n	,,	,,	962
51·41	2	,,	,,	965·5
50·15	1n	,,	,,	975·8
49·40	1	,,	,,	982·3
48·94	1	,,	,,	986·3
48·57	1	,,	,,	989·5
48·36	1	,,	,,	991·3
47·95	1n	,,	,,	994·5
47·47	1n	,,	,,	998·7
46·88	1	,,	,,	29003·3
46·73	1	,,	,,	004·6
46·47	1	,,	,,	006·7
46·23	1	,,	,,	008·9
46·00	1	,,	,,	010·9
45·83	1	,,	,,	012·4
45·45	1n	,,	,,	015·7
45·15	1n	,,	,,	018·3
44·90	1	,,	,,	020·2
44·85	1	,,	,,	020·6
44·53	1	,,	,,	023·4
43·97	1n	,,	,,	028·6
43·66	1	,,	,,	031·0
43·10	1	,,	,,	035·4
42·80	1	,,	,,	038·0
42·55	1	,,	,,	040·5
42·45	1	,,	,,	041·3
41·95	1	,,	,,	045·1

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3441·65	1n	0·96	8·2	29047·7
41·15	1	,,	,,	051·9
40·74	1	,,	,,	055·3
40·37	1	,,	,,	058·5
40·20	1	,,	,,	059·9
40·07	1	,,	,,	061·0
39·58	1	,,	,,	065·1
39·25	1	,,	,,	068·0
38·84	1	,,	,,	071·5
38·56	1	,,	,,	073·9
38·08	1	,,	,,	077·8
37·31	1	,,	,,	084·2
37·18	1	,,	,,	085·3
36·93	2	,,	,,	087·5
36·20	1	,,	,,	093·7
35·65	2	,,	,,	098·4
35·32	1	,,	,,	101·2
34·92	1	,,	,,	104·4
34·70	1	,,	,,	106·3
34·42	2	,,	,,	109·2
33·85	1	,,	,,	113·6
33·6	1b	,,	,,	116
33·2	1b	,,	,,	119·5
32·67	1	,,	8·3	123·5
32·15	1	,,	,,	127·9
31·65	1	,,	,,	132·2
31·23	1	,,	,,	135·8
30·87	1n	,,	,,	138·8
30·60	1	,,	,,	141·2
30·35	1	,,	,,	143·2
29·47	1n	,,	,,	150·7
29·05	1n	,,	,,	154·3
28·30	1b	,,	,,	160.7
28·06	1	,,	,,	162·7
27·90	1	,,	,,	164·1
27·58	1	,,	,,	166·7
27·20	1	,,	,,	170·0
26·72	1	,,	,,	174·1
26·52	2	,,	,,	175·8
25·97	1	,,	,,	180·5
25·66	1n	,,	,,	183·4
25·48	1n	,,	,,	184·7
25·25	1n	,,	,,	186·6
24·96	1	,,	,,	189·1
24·69	1	,,	,,	191·4
24·45	1	,,	,,	193·5
24·25	1	,,	,,	195·2
23·9	1n	,,	,,	198
23·16	2	,,	,,	204·5
22·63	1	,,	,,	209·0
22·45	1	,,	,,	210·5
21·85	2	,,	,,	215·7
21·52	1	,,	,,	218·5
21·30	1	,,	,,	217·3
21·17	1	,,	,,	221·5

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3420·67	1nd	0·96	8·3	29225·7
20·22	1	,,	,,	229·6
20·02	1	,,	,,	231·3
19·72	1n	,,	,,	233·9
19·55	1n	,,	,,	235·3
19·20	1n	,,	,,	232·9
18·73	1n	,,	,,	242·3
18·55	1n	,,	,,	243·9
18·30	1	,,	,,	246·0
17·62	1	0·95	,,	251·8
17·50	1	,,	,,	252·8
17·00	1	,,	,,	257·1
16·70	1	,,	,,	259·7
16·46	1	,,	,,	261·8
16·28	1	,,	,,	263·3
16·04	1	,,	,,	265·4
15·75	1	,,	,,	267·8
15·53	1n	,,	,,	269·7
14·80	1n	,,	,,	276·0
14·50	1	,,	,,	278·6
14·00	2	,,	,,	282·8
13·50	1n	,,	,,	287·1
13·22	1n	,,	,,	289·5
12·90	1n	,,	,,	292·3
12·50	2	,,	,,	295·7
12·26	2	,,	,,	297·8
11·70	1	,,	,,	302·6
11·40	1	,,	,,	305·2
11·25	1	,,	,,	305·5
10·75	1	,,	,,	310·8
10·55	1	,,	,,	312·5
10·31	1	,,	,,	320·1
09·96	1	,,	8·3	317·6
09·85	1	,,	,,	318·5
09·52	1	,,	,,	320·3
09·36	1	,,	,,	322·7
09·11	1	,,	,,	324·9
08·96	1	,,	,,	326·2
08·74	1	,,	,,	328·0
08·17	1n	,,	,,	333·0
08·03	1	,,	,,	334·2
07·50	1	,,	,,	338·7
07·05	1	,,	,,	342·6
06·76	1	,,	,,	345·1
06·44	1	,,	,,	347·9
05·88	1	,,	,,	352·7
05·73	1	,,	,,	354·1
05·32	1n	,,	,,	357·5
05·08	1	,,	,,	359·6
04·40	1	,,	,,	365·4
04·02	1	,,	,,	368·7
03·72	1	,,	,,	371·3
03·37	1n	,,	,,	374·4
02·90	1	,,	,,	378·3
02·60	1d	,,	,,	381·0

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3402·03	1	0·95	8·3	29385·9
01·37	1	,,	,,	391·6
01·15	1	,,	,,	393·5
00·90	1	,,	,,	395·5
00·66	1	,,	,,	397·8
00·45	1	,,	,,	399·5
00·35	1	,,	,,	400·4
00·06	1	,,	,,	402·9
3399·83	1	,,	,,	404·9
99·64	1	,,	,,	406·6
99·40	1	,,	,,	408·6
98·75	1	,,	,,	414·3
98·40	1	,,	,,	417·2
98·10	1	,,	,,	419·9
97·75	1	,,	,,	422·9
97·30	1b	,,	,,	426·8
97·10	1b	,,	,,	428·6
96·71	1	,,	8·4	432·0
96·58	1	,,	,,	433·0
96·20	1	,,	,,	436·2
95·73	2	,,	,,	440·3
95·48	2	,,	,,	442·4
94·92	2	,,	,,	447·4
94·45	1	,,	,,	451·5
94·05	2	,,	,,	459·9
93·33	1	,,	,,	461·2
93·12	1	,,	,,	463·0
92·81	1	,,	,,	465·7
92·50	1b	,,	,,	466·3*
91·37	1	,,	,,	478·2
91·19	1	,,	,,	479·8
90·98	1	,,	,,	481·6
90·45	2	,,	,,	486·2
90·10	1n	,,	,,	489·2
89·88	1	,,	,,	491·2
89·50	1n	,,	,,	594·5
89·21	1d	,,	,,	597·0
88·65	1n	,,	,,	500·9
88·50	1n	,,	,,	503·2
88·17	1n	,,	,,	506·1
87·30	1b	,,	,,	513·6
86·65	1n	,,	,,	519·3
86·26	2	,,	,,	522·7
85·79	1	,,	,,	526·8
85·50	1	,,	,,	529·3
84·7	1n	,,	,,	536
84·58	1	,,	,,	537·4
84·37	1	,,	,,	539·2
84·15	1	,,	,,	541·1
83·94	1	,,	,,	542·9
83·55	1	,,	,,	546·3
82·80	1	,,	,,	552·9
82·45	1	,,	,,	556·0
82·11	2	,,	,,	565·0
81·00	1	,,	,,	568·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3380·83	2	0·95	8·4	29570·1
80·37	1n	,,	,,	574·2
79·95	1	,,	,,	577·8
79·80	1	,,	,,	579·1
79·52	1	,,	,,	581·6
79·00	1n	,,	,,	586·1
78·87	1n	,,	,,	587·3
78·40	1n	,,	,,	591·5
78·15	1n	,,	,,	593·6
77·55	1	0·94	,,	598·9
77·20	1b	,,	,,	601·9
76·68	1	,,	,,	606·5
75·95	2	,,	,,	612·9
75·05	1	,,	,,	620·8
74·6	1n	,,	,,	623
74·32	1	,,	,,	627·2
74·22	1	,,	,,	628·1
73·84	1	,,	,,	631·4
73·57	1n	,,	,,	633·8
73·20	1n	,,	,,	637·0
72·74	1nd	,,	,,	640·1
72·18	1	,,	,,	646·0
71·45	2	,,	,,	652·4
71·15	1	,,	,,	655·1
71·06	1	,,	,,	656·1
70·83	1	,,	,,	657·9
70·60	1	,,	,,	659·8
70·28	1	,,	,,	662·7
70·11	1	,,	,,	666·2
69·82	1	,,	,,	666·8
69·4	1b	,,	,,	669·5
69·00	1	,,	,,	674·0
68·90	1	,,	,,	674·9
68·44	1	,,	,,	678·9
68·02	1	,,	,,	682·6
67·85	1	,,	,,	684·1
67·68	1	,,	,,	685·6
67·50	1	,,	,,	687·2
66·99	1	,,	,,	692·5
66·70	1	,,	,,	694·3
66·50	1	,,	,,	696·0
65·77	1n	,,	,,	702·5
65·30	1n	,,	,,	706·6
64·78	1n	,,	,,	711·2
64·05	1n	,,	,,	717·7
63·60	1	,,	,,	721·5
63·40	1	,,	,,	723·5
62·87	1n	,,	,,	728·5
62·15	1n	,,	,,	734·4
61·86	1	,,	,,	737·0
61·37	1	,,	8·5	741·3
60·97	1	,,	,,	744·8
60·80	1	,,	,,	746·3
60·50	1	,,	,,	749·0
60·27	1	,,	,,	751·0

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3359·73	1	0·94	8·5	29755·8
59·2	1n	,,	,,	760·5
59·05	1n	,,	,,	761·8
58·75	1	,,	,,	764·5
58·60	1	,,	,,	765·7
58·06	2	,,	,,	770·6
57·70	1n	,,	,,	773·8
57·32	1n	,,	,,	777·3
56·65	1n	,,	,,	783·1
56·35	1	,,	,,	785·8
56·15	1	,,	,,	787·6
56·00	1	,,	,,	788·9
55·56	1n	,,	,,	792·8
55·24	1	,,	,,	778·0
54·94	1	,,	,,	798·3
54·65	2	,,	,,	799·9
54·22	1n	,,	,,	805·7
53·75	1	,,	,,	808·9
53·40	1	,,	,,	812·0
53·20	1	,,	,,	812·9
52·81	1	,,	,,	817·2
51·98	1	,,	,,	824·6
51·83	1	,,	,,	825·9
51·40	1	,,	,,	829·8
51·05	1	,,	,,	832·9
50·80	1d	,,	,,	835·7
50·45	1n	,,	,,	838·2
50·20	1n	,,	,,	840·5
49·56	2	,,	,,	845·6
49·19	1	,,	,,	849·4
48·85	1n	,,	,,	852·5
48·45	1n	,,	,,	856·0
48·00	1	,,	,,	860·1
47·72	1	,,	,,	862·5
47·17	1	,,	,,	867·5
46·87	1	,,	,,	870·1
46·56	1	,,	,,	872·9
46·35	1	,,	,,	874·8
46·13	1	,,	,,	876·8
46·00	1	,,	,,	877·9
45·67	1	,,	,,	880·9
45·00	2	,,	,,	886·9
44·45	1n	,,	,,	891·8
44·2	1b	,,	,,	894
43·60	1	,,	,,	899·4
43·1	1n	,,	,,	904
42·83	2	,,	,,	906·3
42·5	1n	,,	,,	909
41·83	2	,,	,,	915·2
41·1	1n	,,	,,	922
40·80	1n	,,	,,	924·5
40·47	1	,,	,,	927·4
40·23	1	,,	,,	929·6
39·56	1	,,	,,	935·6
39·37	1	,,	,,	937·3

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3339·15	1	0·94	8·5	29939·2
39·00	1	,,	,,	940·6
38·62	1	0·93	,,	943·0
38·10	1	,,	,,	948·7
37·93	2	,,	,,	950·2
37·50	1	,,	,,	954·0
36·84	1	,,	,,	960·0
36·42	1	,,	,,	963·7
36·12	1n	,,	,,	966·3
35·78	1	,,	,,	969·5
35·4	1b	,,	,,	973
34·99	1	,,	,,	976·6
34·60	1	,,	,,	980·1
34·40	1	,,	,,	981·9
34·10	1	,,	,,	984·6
33·40	1	,,	,,	990·9
32·60	1d	,,	,,	998·1
32·12	1	,,	,,	30001·3
31·93	1	,,	,,	004·1
31·45	1	,,	,,	008·5
31·12	1	,,	,,	011·4
30·93	1	,,	,,	013·2
30·65	1	,,	,,	015·5
30·50	1	,,	,,	017·0
30·08	2d (Mg)	,,	,,	022·2
29·65	1	,,	,,	024·7
29·47	1	,,	,,	026·3
29·15	1	,,	,,	029·2
28·70	1	,,	,,	033·3
28·40	1	,,	,,	036·0
27·66	1	,,	,,	042·7
27·42	1	,,	,,	044·8
27·20	1	,,	,,	046·8
26·88	1	,,	,,	050·5
26·52	1	,,	,,	053·4
26·32	1	,,	,,	055·2
25·84	1	,,	,,	059·1
25·36	1n	,,	,,	063·4
24·77	1n	,,	,,	068·5
23·50	1n	,,	8·6	080 0
23·25	1	,,	,,	082·1
23·13	1	,,	,,	083·5
22·83	1	,,	,,	086·1
22·55	1	,,	,,	088 7
22·26	1	,,	,,	091·4
21·9	1n	,,	,,	095
21·51	1	,,	,,	098·3
21·37	1	,,	,,	099·5
21·07	1	,,	,,	002 2
20·46	1	,,	,,	007·7
19·46	2	,,	,,	016·9
19·00	1	,,	,,	121·0
18·43	1	,,	,,	126·2
18·35	1	,,	,,	126·9
17·99	1	,,	,,	130·1

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3317·62	1	0·93	8·6	30133·5
17·37	1	„	„	135·7
16·90	1	„	„	140·0
16·7	1b	„	„	142
16·1	1b	„	„	147
15·23	1	„	„	155·2
14·73	1	„	„	159·8
14·22	1	„	„	164·4
14·13	1	„	„	165·2
13·91	1	„	„	167·2
13·25	1n	„	„	173·2
12·64	1	„	„	178·8
12·0	1n	„	„	185
11·87	2	„	„	185·8
11·55	1n	„	„	188·8
11·1	1nd	„	„	193
10·65	1	„	„	197·1
09·82	1	„	„	204·5
09·45	1	„	„	207·9
09·37	1	„	„	208·7
09·08	1	„	„	211·3
08·60	1n	„	„	215·7
08·40	1n	„	„	217·5
08·1	1n	„	„	220
07·72	2	„	„	223·7
07·4	1b	„	„	227
06·7	1	„	„	233
06·39	1	„	„	235·8
06·06	3	„	„	238·8
05·3	1b	„	„	246
04·85	1n	„	„	250·0
03·73	1	„	„	262·0
03·46	1	„	„	262·7
03·17	1	„	„	265·3
03·02	1	„	„	266·7
02·67	1	„	„	269·8
02·43	1	„	„	272·1
01·97	1	„	„	276·4
01·75	1	„	„	278·4
01·47	1	„	„	280·9
01·32	1	„	„	282·3
00·95	1	„	„	285·7
00·87	1	„	„	286·4
00·6	1	„	„	289
00·33	1	„	„	291·4
3299·99	1	0·92	„	294·5
99·86	1	„	„	295·7
99·25	1	„	„	301·1
98·61	1	„	„	307·0
98·06	2	„	„	312·3
97·72	1	„	„	315·4
97·3	1	„	„	319
96·95	1	„	„	322·5
96·67	1	„	„	325·0
96·42	1	„	„	327·3

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3295·95	1	0·92	8·6	30331·7
95·69	1	,,	,,	334·1
95·37	1	,,	,,	337·0
95·00	1	,,	,,	340·4
94·28	1n	,,	,,	347·0
94·13	1	,,	,,	348·2
93·77	1	,,	,,	351·7
93·15	1	,,	,,	357·5
92·51	1	,,	,,	363·4
91·51	3	,,	,,	372·6
91·23	1	,,	,,	375·5
91·10	1	,,	,,	376·4
90·63	1	,,	,,	380·7
90·27	1	,,	,,	384·0
89·60	1	,,	,,	390·3
89·50	1	,,	,,	391·2
88·75	1	,,	8·7	398·0
88·38	2	,,	,,	401·4
88·06	1	,,	,,	404·4
87·63	2	,,	,,	408·3
86·8	1n	,,	,,	416
86·63	1	,,	,,	417·6
86·42	1	,,	,,	419·6
86·09	1	,,	,,	422·6
85·76	1	,,	,,	425·6
85·44	2	,,	,,	428·6
85·20	1	,,	,,	430·8
84·80	1	,,	,,	434·5
84·53	1	,,	,,	437·1
84·17	1	,,	,,	440·4
83·92	1	,,	,,	442·7
83·30	1n	,,	,,	448·5
82·8	1n	,,	,,	453
82·68	1	,,	,,	454·2
82·3	1n	,,	,,	459
81·83	1	,,	,,	462·1
81·70	1	,,	,,	464·3
81·26	1	,,	,,	468·4
80·95	1	,,	,,	470·3
80·80	1	,,	,,	471·7
80·53	1	,,	,,	474·1
80·20	1	,,	,,	477·2
79·75	1	,,	,,	481·4
79·38	1	,,	,,	484·9
79·25	1	,,	,,	486·0
78·6	1b	,,	,,	492·1
77·7	2b	,,	,,	500·5
77·27	1	,,	,,	504·5
76·80	1	,,	,,	508·9
76·32	1	,,	,,	513·3
75·6	1b	,,	,,	520
74·70	1	,,	,,	528·5
74·40	1	,,	,,	531·3
74·12	1	,,	,,	533·9
73·65	1n	,,	,,	538·3

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3273·45	1n	0·92	8·7	30540·1
73·25	1n	,,	,,	542·0
72·75	1n	,,	,,	546·6
72·33	1n	,,	,,	550·6
71·65	1	,,	,,	556·9
71·3	1b	,,	,,	560
70·73	1	,,	,,	565·5
70·32	2	,,	,,	569·3
69·95	1	,,	,,	572·8
69·65	1	,,	,,	575·6
69·20	1	,,	,,	579·8
68·95	1n	,,	,,	582·2
68·8	1n	,,	,,	584
68·35	1	,,	,,	587·8
67·93	1	,,	,,	591·7
67·80	1	,,	,,	592·9
67·40	1	,,	,,	596·7
67·17	1	,,	,,	599·8
66·68	1	,,	,,	603·4
66·35	1	,,	,,	606·5
66·07	1	,,	,,	609·1
65·99	2	,,	,,	609·9
64·83	1n	,,	,,	620·8
64·55	1n	,,	,,	623·4
63·93	1	,,	,,	639·2
63·67	1	,,	,,	631·6
63·28	1	,,	,,	635·3
63·00	1	,,	,,	637·9
62·80	1	,,	,,	639·8
61·89	1	,,	,,	648·4
61·27	1	,,	,,	654·2
61·15	1	,,	,,	655·3
61·05	1	,,	,,	656·3
60·70	1	,,	,,	659·6
59·99	1	0·91	,,	666·2
59·65	1n	,,	,,	669·4
59·08	1n	,,	,,	674·3
58·55	1	,,	,,	679·8
58·23	1	,,	,,	682·8
57·95	1	,,	,,	685·4
57·50	1	,,	,,	689·7
57·40	1	,,	,,	690·6
56·88	1	,,	,,	695·5
56·60	1	,,	,,	698·2
56·18	1	,,	,,	602·1
55·50	1	,,	,,	708·5
55·20	1	,,	,,	711·4
55·00	1	,,	,,	713·3
54·73	1n	,,	,,	715·8
54·44	1	,,	,,	718·5
53·50	1	,,	,,	727·4
52·95	1n	,,	,,	732·6
52·80	1	,,	,,	733·9
52·50	1	,,	,,	736·8
52·3	1n	,,	,,	739

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3251·15	1n	0·91	8·7	30749·6
51·00	1	,,	,,	751·0
50·50	1	,,	,,	755·7
50·07	1	,,	,,	759·8
49·62	1	,,	,,	764·0
49·37	1	,,	,,	766·4
49·12	1	,,	,,	768·8
48·52	1	,,	,,	774·5
48·17	1	,,	,,	777·8
47·96	1	,,	,,	779·8
47·75	1	,,	,,	781·8
47·43	1	,,	,,	784·8
46·55	1	,,	,,	793·1
46·33	2	,,	,,	795·2
45·95	1n	,,	,,	798·8
44·98	1	,,	,,	808·0
44·69	1	,,	,,	810·7
44·39	2	,,	,,	813·6
43·85	1	,,	,,	818·8
42·90	1d	,,	,,	827·8
42·17	1	,,	,,	834·7
41·77	1	,,	,,	838·5
41·30	1	,,	,,	843·0
41·00	1	,,	,,	845·9
40·55	1	,,	,,	850·2
40·30	1	,,	,,	851·6
39·80	1	,,	,,	857·3
39·65	1	,,	,,	858·7
38·62	1	,,	,,	868·6
38·10	1n	,,	,,	873·5
37·4	1b	,,	,,	880
36·93	1	,	,,	884·7
36·4	1n	,,	,,	890
35·44	1	,,	,,	898·9
35·20	1n	,,	,,	901·2
34·70	1n	,,	,,	906·0
34·14	1n	,,	,,	911·3
33·53	1	,,	,,	917·1
32·83	1n	,,	,,	923·8
32·33	2	,,	,,	928·6
32·13	1	,,	,,	930·5
31·2	1b	,,	,,	939·5
30·3	1b	,,	,,	948
29·65	3	,,	,,	954·3
28·7	1b	,,	,,	963
27·6	1b	,,	,,	974
27·33	1	,,	,,	976·5
26·97	1	,,	,,	980·0
26·33	2	,,	,,	986·2
25·9	1n	,,	,,	990
24·45	2	,,	,,	31004·2
23·88	1	,,	,,	009·7
23·65	1	,,	,,	011·9
23·2	1b	,,	,,	016
22·65	1	,,	,,	021·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3222·46	1	0·91	8·7	31023·4
22·16	1	,,	,,	026·3
21·55	1n	,,	,,	032·1
19·9	1n	0·90	,,	048
19·36	1	,,	,,	053·3
18·50	2	,,	,,	061·6
18·29	1	,,	,,	063·6
17·89	1	,,	,,	067·5
17·18	1	,,	,,	074·3
16·75	1	,,	,,	078·5
16·13	1	,,	,,	084·5
15·29	1	,,	,,	092·6
14·96	1	,,	,,	095·8
14·87	1	,,	,,	096·7
14·42	1	,,	,,	100·9
14·05	1	,,	,,	104·5
13·80	1	,,	,,	106·9
13·52	1	,,	,,	109·7
13·25	1	,,	,,	112·3
12·77	1	,,	,,	116·9
12·00	1	,,	,,	124·3
11·45	1n	,,	,,	129·7
11·20	1	,,	,,	132·1
10·8	1b	,,	,,	136
10·10	1	,,	,,	142·8
09·8	1	,,	,,	146
09·32	1	,,	,,	150·3
08·7	1b	,,	,,	156
08·27	1n	,,	,,	160·5
07·4	1b	,,	,,	169
06·37	1	,,	,,	179·0
06·18	1	,,	,,	180·9
05·9	1n	,,	,,	184
05·25	1	,,	,,	189·9
04·79	1	,,	,,	194·4
04·45	1	,,	,,	197·7
03·9	1nd	,,	,,	223
03·55	1	,,	,,	206·5
03·38	1	,,	,,	208·1
02·95	1n	,,	,,	212·3
02·65	1n	,,	,,	215·2
01·75	1	,,	,,	203·1
01·4	1b	,,	,,	227·5
00·80	1	,,	,,	233·3
00·30	2	,,	,,	238·2
3199·75	1	,,	,,	243·5
99·38	1	,,	,,	247·2
99·0	1nd	,,	,,	251
98·45	1n	,,	,,	256·2
98·30	1	,,	,,	257·7
96·90	1	,,	,,	271·4
96·2	1b	,,	,,	278
95·7	1b	,,	,,	283
95·0	1b	,,	,,	290
94·1	1b	,,	,,	299

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3193·45	1	0·90	8·7	31304·9
93·36	1	,,	,,	305·8
92·82	1	,,	,,	311·2
92·30	1	,,	,,	316·4
91·90	1	,,	,,	320·4
91·02	1	,,	,,	329·2
90·86	1	,,	,,	330·8
90·6	1n	,,	,,	333
89·65	1	,,	,,	342·7
89·17	1	,,	,,	347·2
88·50	1n	,,	,,	353·8
87·65	1n	,,	,,	362·2
86·35	1n	,,	,,	375·0
85·85	1	,,	,,	379·9
85·33	1n	,,	,,	385·0
84·9	1b	,,	,,	389
84·60	1b	,,	,,	392·3
84·15	1n	,,	,,	396·7
83·63	1	,,	,,	401·8
83·00	1	,,	,,	408·0
82·72	1	,,	,,	410·8
81·5	1n	,,	,,	423
81·2	1b	,,	,,	426
80·75	1n	,,	,,	430·1
80·48	1n	,,	,,	432·8
80·33	1	,,	,,	434·3
79·98	1	,,	,,	437·7
79·50	1	,,	,,	442·4
79·18	1	,,	,,	445·6
79·03	1	,,	,,	447·1
78·45	1	,,	,,	452·9
77·79	1	,,	,,	459·4
77·48	2	,,	,,	462·5
76·78	1	,,	,,	469·4
76·34	2	,,	,,	474·8
75·50	1	,,	,,	482·1
74·96	1	,,	,,	487·5
74·15	1	,,	,,	495·5
73·82	1	,,	,,	498·8
72·8	1b	,,	,,	509
72·24	1n	,,	,,	514·5
71·95	1	,,	,,	517·3
71·53	1	,,	,,	521·6
71·22	1	,,	,,	524·6
70·96	1	,,	,,	527·2
70·69	1	,,	,,	529·9
70·48	1	,,	,,	532·0
70·2	1b	,,	,,	535
69·2	1b	,,	,,	545
68·55	1n	,,	,,	551·2
68·33	1n	,,	,,	553·4
67·9	1b	,,	,,	558
67·22	2	,,	,,	564·5
66·64	1	,,	,,	570·3
65·62	1	,,	,,	580·5

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3165·41	1	0·90	8·7	31582·6
65·20	1	,,	,,	584·6
64·29	1	,,	,,	593·7
63·90	1	,,	,,	597·6
63·10	1	,,	,,	605·6
62·95	1	,,	,,	607·0
62·4	1b	,,	,,	612·6
61·95	1	,,	,,	617
61·66	1	,,	,,	620·0
60·90	1	,,	,,	627·6
60·48	1	,,	,,	631·8
60 06	1	,,	,,	636·0
59·94	1	,,	,,	637·2
59·41	1	,,	,,	642·5
59·06	1	,,	,,	646·0
58·7	1n	,,	,,	650
58·3	1n	,,	,,	654
57·97	1	,,	,,	656·9
57·57	1	,,	,,	660·9
56·70	1	,,	,,	669·6
56·22	2	,,	,,	674·4
55·98	1	,,	,,	676·9
55·53	1	,,	,,	681·4
55·40	1	,,	,,	682·7
55·02	1	,,	,,	686·5
54·55	1d	,,	,,	691·2
54·30	1n	,,	,,	693·8
53·62	1	,,	,,	700·5
53·36	2	,,	,,	703·2
52·57	1	,,	,,	711·1
52·45	1	,,	,,	712·3
51·81	1	,,	,,	718·8
51·2	1b	,,	,,	725
50·90	1	,,	,,	728·0
50·62	1	,,	,,	730·8
50·50	1	,,	,,	732·0
50·10	1n	,,	,,	736·0
49·76	1	,,	,,	739 4
49·34	2	,,	,,	743·6
49·17	1	,,	,,	745·3
48·85	1	,,	,,	748·6
48·73	1	,,	,,	749·8
48·40	1	,,	,,	753·2
48·28	1	,,	,,	754·4
47·93	1	,,	,,	757·9
47·19	2	,,	,,	765·4
46·85	1	,,	9·1	768·8
46 43	1	,,	,,	773·0
46·2	1n	,,	,,	775
45·67	1	,,	,,	780·7
45·47	1	,,	,,	782·7
45·09	1	,,	,,	786·5
44·84	1	,,	,,	789·1
43·45	1n	,,	,,	803·1
42·74	1	,,	,,	810·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3142·46	1	0·90	9·1	31813·2
42·03	1	,,	,,	817·5
41·75	1	0·88	,,	820·4
39·69	2	,,	,,	841·3
39·29	1	,,	,,	845·3
38·99	1	,,	,,	848·3
38·6	1n	,,	,,	852
38·4	1n	,,	,,	854
37·85*	1	,,	,,	859·9
37·01	1	,,	,,	868·4
36·30	1n	,,	,,	875·6
35·92	1	,,	,,	879·5
34·9	1b	,,	,,	890
33·99	1	,,	,,	899·1
33·69	1	,,	,,	902·2
33·50	1n	,,	,,	904·1
32·75	1	,,	,,	911·7
32·32	1n	,,	,,	916·1
32·07	1	,,	,,	918·7
31·72	1n	,,	,,	922·2
31·42	1n	,,	,,	925·3
30·67	2n	,,	,,	933·0
29·86	2	,,	,,	949·2
28·88	1n	,,	,,	951·2
28·20	1n	,,	,,	958·2
27·75	1n	,,	,,	962·8
27·35	1	,,	,,	966·9
26·78	1	,,	,,	972·7
26·28	2	,,	,,	977·8
25·03	2	,,	,,	990·6
24·53	1	,,	,,	995·7
24·28	1	,,	,,	998·3
23·82	1	,,	,,	32003·0
23·70	1	,,	,,	004·2
22·8	1n	,,	,,	013·5
22·43	1n	,,	,,	017·2
21·97	1n	,,	,,	022·0
21·49	1	,,	,,	026·9
21·15	1	,,	,,	030·4
20·97	1	,,	,,	032·1
20·77	1n	,,	,,	034·4
20·25	1n	,,	,,	039·6
19·99	1n	,,	,,	042·3
19·42	2	,,	,,	048·2
19·13	1n	,,	,,	051·1
18·88	1n	,,	,,	053·7
18·51	1n	,,	,,	057·5
18·13	1	,,	,,	061·3
17·75	1	,,	,,	065·8
17·14	1	,,	,,	071·6
16·83	1	,,	,,	074·8
16·53	1	,,	,,	077·9
16·02	2	,,	,,	083·0

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URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3115·12	1	0·88	9·1	32092·4
14·75	1	,,	9·2	096·1
14·42	1n	,,	,,	099·5
13·75	1	,,	,,	106·4
13·16	1	,,	,,	112·5
12·50	1n	,,	,,	119·3
12·35	1n	,,	,,	120·9
11·76	1	,,	,,	127·0
11·52	1	,,	,,	129·5
10·96	1	,,	,,	135·2
10·65	1	,,	,,	138·4
10·3	1n	,,	,,	142
09·9	1n	,,	,,	146
09·4	1n	,,	,,	151
08·79	1n	,,	,,	157·6
08·43	1n	,,	,,	161·4
08·07	1n	,,	,,	165·1
07·79	1n	,,	,,	168·0
07·65	1n	,,	,,	169·5
07·47	1n	,,	,,	171·3
06·9	1b	,,	,,	177
06·42	1	,,	,,	180·2
06·29	1	,,	,,	183·6
05·73	1	,,	,,	189·4
05·50	1	,,	,,	191·7
05·20	1	,,	,,	194·8
04·8	1b	,,	,,	199
04·27	2	,,	,,	204·5
03·87	1	,,	,,	208·7
03·10	1	,,	,,	216·7
02·70	1n	,,	,,	220·8
02·55	1	,,	,,	222·4
01·85	1n	0·87	,,	229·7
01·05	1n	,,	,,	237·9
00·97	1n	,,	,,	239·8
00·23	1n	,,	,,	246·5
3099·9	1n	,,	,,	250
99·4	1n	,,	,,	255
99·2	1n	,,	,,	257
98·88	1	,,	,,	260·5
98·77	1	,,	,,	261·7
98·15	1	,,	,,	268·1
97·00	1	,,	,,	280·1
96·70	1	,,	,,	283·2
95·97	1	,,	,,	290·9
95·85	1	,,	,,	292·1
95·33	1	,,	,,	297·5
95·15	1	,,	,,	299·3
94·92	1	,,	,,	301·8
94·57	1	,,	,,	305·4
93·97	1	,,	,,	311·7
93·51	1	,,	,,	316·5
93·15	2	,,	,,	320·3
91·7	1b	,,	,,	335·5
91·4	1b	,,	,,	339

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3090·70	1n	0·87	9·2	32346·0
90·45	1n	"	"	348·5
89·98	1n	"	"	353·5
89·10	1	"	"	362·7
88·68	1n	"	"	367·1
88·05	1	"	"	373·7
87·80	1	"	"	376·3
87·23	1	"	"	381·3
86·90	1	"	"	385·8
86·13	1n	"	"	393·8
85·60	1n	"	"	399·3
84·8	1b	"	"	408
84·37	1	"	"	412·3
83·75	1n	"	9·3	418·8
83·2	1b	"	"	424·5
82·7	1b	"	"	430
82·14	1	"	"	435·7
81·18	1	"	"	445·8
80·83	1	"	"	449·5
80·10	1	"	"	457·2
79·40	1n	"	"	464·5
79·05	1n	"	"	468·1
78·55	1n	"	"	473·5
77·95	1n	"	"	479·9
77·7	1n	"	"	482·5
77·50	1n	"	"	484·6
76·7	1b	"	"	493·1
76·2	1b	"	"	498
75·93	1	"	"	512
75·60	1	"	"	505·7
75·15	1	"	"	509·4
74·62	1n	"	"	515·1
74·47	1n	"	"	516·7
73·93	1	"	"	522·3
73·60	1	"	"	526·8
73·3	1b	"	"	529
72·91	2	"	"	533·2
72·47	1	"	"	537·8
71·87	1	"	"	549·2
71·6	1b	"	"	548
71·17	1	"	"	551·6
70·80	1	"	"	555·5
70·40	1	"	"	558·8
69·6	1b	"	"	569
69·3	1b	"	"	571
68·74	1	"	"	577·4
67·85	1n	"	"	586·8
67·37	1	"	"	591·9
67·00	1	"	"	595·8
66·43	1	"	"	601·9
65·8	1b	"	"	609
65·4	1b	"	"	612
65·02	1	"	"	616·9
64·70	1	"	"	620·3
64·30	1	"	"	624·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3063·98	1	0·87	9·3	32628·0
63·62	1	,,	,,	631·8
63·25	1n	,,	,,	635·8
62·97	1	0·86	,,	638·7
62·62	1	,,	,,	642·5
62·23	1d	,,	,,	646·6
61·74	1	,,	,,	519·3
61·30	1n	,,	,,	656·9
60·80	1	,,	,,	661·9
60·15	1	,,	,,	668 8
59·68	1	,,	,,	673·9
59·3	1n	,,	,,	678
59·1	1n	,,	,,	680
58·05	2r	,,	,,	691·3
57·35	1n	,,	,,	698·8
56·83	1	,,	,,	703·3
55·99	1	,,	,,	713·3
55·71	1	,,	,,	716·3
55·18	1	,,	,,	722·0
54·86	1	,,	,,	725·3
54·5	1b	,,	,,	729
53·42	1	,,	9·4	740·4
52·96	1	,,	,,	745·7
52·56	1	,,	,,	750·0
52·00	1	,,	,,	756·0
51·43	1	,,	,,	761·9
51·20	1	,,	,,	764·6
50·61	1d	,,	,,	771·0
50·30	1	,,	,,	774·3
49·9	1b	,,	,,	778·5
49·05	1n	,,	,,	787·7
48·75	1	,,	,,	791·0
48·45	1	,,	,,	794·2
47·98	1	,,	,,	799·2
47·66	1	,,	,,	802·8
46·96	1	,,	,,	810·2
46·6	1	,,	,,	814
45·55	1	,,	,,	825·4
45·1	1n	,,	,,	830
44·26	2	,,	,,	839·3
44·1	1n	,,	,,	841
43·3	1b	,,	,,	850
42·85	1n	,,	,,	854·5
42·0	1b	,,	,,	864
41·3	1b	,,	,,	871
40·6	1b	,,	,,	881
40·00	1	,,	,,	885·3
39·3	1n	,,	,,	893
38·58	1n	,,	,,	900·7
38·01	2	,,	,,	906·9
37·63	1n	,,	,,	910·9
37·38	1n	,,	,,	913·7
36·7	1n	,,	,,	921
36·53	1n	,,	,,	923·0
36·05	1	,,	,,	928·1

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3035·60	1	0·86	9·4	32933·0
34·50	1	,,	,,	945·5
34·15	1	,,	,,	948·8
33·86	1	,,	,,	952·0
33·52	1	,,	,,	955·6
33·27	1	,,	,,	958·3
32·52	1	,,	,,	966·4
32·09	1	,,	,,	971·1
31·65	1n	,,	,,	975·4
30·9	1b	,,	,,	984
30·45	1	,,	,,	989·0
29·52	1	,,	,,	999·2
29·23	1	,,	,,	33003·4
28·7	1n	,,	,,	008
28·48	1	,,	,,	010·5
28·33	1	,,	,,	012·1
27·77	1	,,	,,	018·2
26·99	1n	,,	,,	026·7
26·77	1	,,	,,	029·1
26·55	1n	,,	,,	031·5
26·25	1	,,	9·5	045·6
25·16	1	,,	,,	046·6
24·57	2	,,	,,	053·1
23·9	1n	,,	,,	060
23·4	1n	,,	,,	066
22·94	1	0·85	,,	070·9
22·58	1	,,	,,	074·9
22·31	2	,,	,,	077·8
21·68	1	,,	,,	084·7
21·30	1	,,	,,	087·8
21·02	1	,,	,,	091·9
20·71	1	,,	,,	095·3
20·35	1	,,	,,	099·3
19·9	1b	,,	,,	104
19·40	1	,,	,,	109·6
18·95	1	,,	,,	114·6
18·68	1	,,	,,	117·6
18·2	1b	,,	,,	123
17·50	1n	,,	,,	133·5
17·05	1	,,	,,	135·5
16·50	1	,,	,,	141·5
16·16	1	,,	,,	145·2
15·78	1	,,	,,	149·4
15·03	1	,,	,,	157·7
14·35	1n	,,	,,	165·1
13·96	1	,,	,,	169·4
13·60	1	,,	,,	173·4
13·49	1	,,	,,	174·6
13·08	1	,,	,,	179·1
12·83	1	,,	,,	179·9
12·22	1	,,	,,	188·6
12·04	1	,,	,,	190·6
11·66	1	,,	,,	194·7
11·30	1	,,	,,	198·7
10·87	1	,,	,,	203·4

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3010·49	1	0·85	9·5	33207·6
09·80	1	,,	,,	215·3
09·51	1	,,	,,	218·6
09·00	1	,,	,,	224·1
08·29	1	,,	,,	232·0
08·02	1	,,	,,	235·0
06·95	1	,,	,,	246·7
06·2	1b	,,	,,	255
05·65	1	,,	,,	261·2
05·23	1	,,	,,	265·8
04·9	1n	,,	,,	269·5
04·70	1	,,	,,	271·6
04·30	1	,,	,,	276·1
04·1	1n	,,	,,	278
03·45	1	,,	,,	285·5
03·17	1	,,	,,	288·6
02·80	1	,,	,,	292·7
02·50	1	,,	,,	296·1
02·15	1	,,	,,	300·0
01·76	1	,,	,,	304·3
01·32	1	,,	,,	309·2
00·90	1n	,,	,,	313·8
00·26	1	,,	,,	329·5
2999·28	1	,,	,,	331·8
99·15	1	,,	,,	333·3
98·50	1n	,,	,,	340·5
98·2	1n	,,	,,	344
97·70	1n	,,	,,	349·4
97·48	1n	,,	9·6	351·5
97·15	1n	,,	,,	355·5
96·90	1n	,,	,,	358·2
96·50	1	,,	,,	362·7
96·2	1n	,,	,,	366
95·9	1n	,,	,,	369
95·6	1n	,,	,,	373
95·00	1d	,,	,,	379·4
94·57	1	,,	,,	384·3
93·80	1	,,	,,	392·8
93·46	1	,,	,,	396·6
92·85	1	,,	,,	403·4
91·8	1b	,,	,,	415
91·10	1n	,,	,,	422·9
90·65	1n	,,	,,	428·6
90·1	1b	,,	,,	434
89·85	1	,,	,,	437·0
89·51	1	,,	,,	440·7
88·05	1n	,,	,,	457·0
87·93	1	,,	,,	458·5
86·35	1n	,,	,,	476·1
85·90	1	,,	,,	481·1
85·24	1	,,	,,	488·6
84·74	1	,,	,,	494·1
84·19	1	,,	,,	490·3
83·85	1	,,	,,	504·1
83·60	1	,,	,,	507·0

URANIUM—*continued.*

Wave-length Spark-Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2982·89	1	0·84	9·6	33514·7
82·40	1n	,,	,,	520·4
81·95	1n	,,	,,	525·5
81·3	1n	,,	,,	533
81·18	1	,,	,,	534·2
80·80	1n	,,	,,	538·4
80·46	1	,,	,,	542·3
79·31	1	,,	,,	555·2
78·30	1	,,	,,	566·6
77·95	1n	,,	,,	570·5
77·41	1	,,	,,	576·7
76·46	1n	,,	,,	587·3
75·97	1	,,	,,	592·9
75·73	1	,,	,,	595·6
75·25	1	,,	,,	601·1
75·0	1b	,,	,,	604
74·2	1b	,,	,,	613
73·40	1	,,	,,	621·9
73·20	1	,,	,,	624·2
72·75	1n	,,	,,	628·3
72·3	1b	,,	,,	634
71·72	1n	,,	,,	641·0
71·17	2	,,	,,	647·2
70·90	1	,,	9·7	650·1
70·56	1	,,	,,	654·0
69·85	1n	,,	,,	662·1
69·6	1n	,,	,,	665
69·35	1n	,,	,,	66·77
68·68	1n	,,	,,	675·3
68·45	1n	,,	,,	677·9
68·02	1	,,	,,	682·9
66·77	1	,,	,,	697·1
66·26	1	,,	,,	702·8
65·8	1n	,,	,,	708
65·5	1n	,,	,,	713·4
65·17	1	,,	,,	715·2
64·76	1	,,	,,	719·9
64·35	1	,,	,,	724·5
63·70	1	,,	,,	731·9
63·30	1	,,	,,	736·5
62·87	1	,,	,,	741·4
61·28	1	,,	,,	759·6
61·02	1	,,	,,	762·4
60·38	1n	,,	,,	769·8
59·96	1	,,	,,	774·4
59·20	1n	,,	,,	783·2
58·25	1n	,,	,,	794·1
57·85	1n	,,	,,	798·7
57·3	1n	,,	,,	805
56·85	1	,,	,,	810·1
56·46	1	,,	,,	814·6
56·15	2	,,	,,	818·1
55·73	1	,,	,,	822·9
55·20	1	,,	,,	829·0
54·92	2	,,	,,	832·2

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2954·46	1	0·84	9·7	33837·4
53·9	1b	,,	,,	844
53·45	1n	,,	,,	849·0
53·0	1n	,,	,,	854
52·85	1n	,,	,,	856·1
52·46	1	,,	,,	860·1
52·00	1	,,	,,	865·6
51·67	1	,,	,,	869·4
51·45	1	,,	,,	871·9
51·16	1	,,	,,	875·3
50·93	1	,,	,,	877·9
50·62	1	,,	,,	881·5
50·37	1	,,	,,	884·4
50·04	1	,,	,,	888·2
49·64	1n	,,	,,	892·8
49·03	1	,,	,,	899·8
48·56	1	,,	,,	905·2
48·12	1n	,,	,,	910·2
47·52	1	,,	,,	917·1
46·8	1b	,,	,,	925
46·38	1n	,,	,,	930·3
45·92	1	,,	,,	935·6
44·73	1n	,,	9·8	949·2
44·62	1	,,	,,	950·5
44·22	1	,,	,,	955·1
43·93	2	,,	,,	958·8
43·50	1	,,	,,	963·9
43·25	1	,,	,,	966·3
42·90	1d	0·83	,,	970·3
42·13	1	,,	,,	978·8
41·95	2	,,	,,	981·2
41·35	1n	,,	,,	988·2
40·80	1	,,	,,	994·5
40·39	2	,,	,,	999·3
40·02	1	,,	,,	003·6
39·50	1	,,	,,	34009·6
38·95	1	,,	,,	015·9
38·60	1n	,,	,,	020·0
38·1	1b	,,	,,	026
37·40	1	,,	,,	033·9
37·23	1n	,,	,,	035·9
37·00	1n	,,	,,	038·5
36·85*	1n	,,	,,	040·4
36·46	1	,,	,,	044·9
35·60	1n	,,	,,	054·8
35·0	1b	,,	,,	062
34·5	1b	,,	,,	068
33·86	1	,,	,,	075·0
33·65	1	,,	,,	077·4
33·33	1n	,,	,,	081·1
33·03	1	,,	,,	084·6
32·65	1	,,	,,	089·0
32·23	1	,,	,,	093·9

* Mg ?

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2931·90	1	0·83	9·8	34097·8
31·60	1	,,	,,	101·3
31·45	1	,,	,,	103·0
30·87	1	,,	,,	109·8
30·68	1	,,	,,	112·0
30·47	1	,,	,,	114·4
29·85	1	,,	,,	121·7
29·70	1	,,	,,	123·3
29·16	1	,,	,,	129·7
28·61	1	,,	,,	136·2
28·16	1	,,	,,	141·3
27·77	1	,,	,,	145·9
27·45	1	,,	,,	149·6
27·30	1	,,	,,	151·4
26·64	1	,,	,,	159·1
26·42	1	,,	,,	161·7
26·18	1	,,	,,	164·5
26·00	1	,,	,,	166·5
25·61	1	,,	,,	182·8
25·25	1	,,	,,	175·3
24·62	1	,,	,,	182·7
23·52	1n	,,	,,	195·6
23·20	1	,,	,,	199·3
22·90	1	,,	,,	202·8
22·71	1	,,	,,	205·0
22·23	1	,,	,,	210·6
22·10	1	,,	,,	212.2
21·76	1	,,	,,	216·2
21·15	1	,,	9·9	223·2
20·77	1	,,	,,	227·6
20·46	1	,,	,,	231·3
20·23	1	,,	,,	234·0
20·00	1	,,	,,	236·7
19·50	1n	,,	,,	242·5
19·08	1	,,	,,	247·5
18·98	1	,,	,,	248·6
18·73	1	,,	,,	251·6
18·48	1n	,,	,,	254·5
17·8	1b	,,	,,	262·5
17·2	1b	,,	,,	269·5
16·90	1n	,,	,,	273·1
16·54	1	,,	,,	277·3
15·80	1n	,,	,,	286·0
15·57*	1	,,	,,	288.7
15·32	1	,,	,,	291·7
14·82	1	,,	,,	297·6
14·69	1	,,	,,	298·1
14·30	1	,,	,,	303·7
14·03	1	,,	,,	306·8
13·50	1	,,	,,	313·1
12·83	1	,,	,,	320·0
12·65	1	,,	,,	323·1
11·90	1	,,	,,	331·9

* Mg ?

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2911·60	1	0·83	9·9	34335·5
11·22	1	,,	,,	340·0
10·88	1	,,	,,	344·0
10·75	1n	,,	,,	345·5
10·3	1b	,,	,,	351
09 78	1n	,,	,,	357·0
09·30	1	,,	,,	362·6
08·8	1b	,,	,,	368·5
08·31	3	,,	,,	374·3
07·65	1nd	,,	,,	382·1
07·00	1n	,,	,,	389·8
06·85	2	,,	,,	391·6
05·8	1b	,,	,,	404
05·32	1	,,	,,	409·7
04·52	2n	,,	,,	419·2
04·07	1	,,	,,	424·6
03·63	1	0·82	,,	429·7
03·08	1	,,	,,	436·3
02·50	1	,,	,,	443·2
02·1	1b	,,	,,	448
01·70	1	,,	,,	451·7
01·27	1	,,	,,	457·9
00·22	1n	,,	,,	470·2
2899·65	1n	,,	,,	477·1
98·80	1	,,	,,	487·1
98·12	1n	,,	,,	491·2
97·70	1	,,	,,	499·2
97·45	1	,,	,,	503·2
97·00	1n	,,	10·0	508·5
96·77	1	,,	,,	511·2
96·52	1	,,	,,	514·2
96·15	1n	,,	,,	517·4
95·96	1	,,	,,	520·9
95 60	1n	,,	,,	525·1
95·30	1	,,	,,	528·7
94·98	1	,,	,,	532·5
94·60	1	,,	,,	537·1
94·20	1	,,	,,	541·9
93·80	1n	,,	,,	546·6
93·5	1b	,,	,,	550
92·70	1	,,	,,	559·8
92 25	1	,,	,,	565·1
91·80	1n	,,	,,	570·5
91·10	1	,,	,,	578·9
90·82	1	,,	,,	582·3
90·50	1	,,	,,	586·1
90·15	1	,,	,,	590·3
89·65	2	,,	,,	596·8
89·32	1	,,	,,	600·2
89·12	1	,,	,,	602·7
88·76	1	,,	,,	606·9
88·42	1	,,	,,	611·0
88·28	1	,,	,,	612·7
87·97	1	,,	,,	616·4
87·65	1	,,	,,	620·2

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3287·31	1	0·92	8·6	30624·3
87·00	1	,,	,,	628·0
86·87	1	,,	,,	629·6
86·50	1	,,	,,	634·0
86·10	1	,,	,,	638·8
35·70	1	,,	,,	643·6
85·49	1	,,	,,	646·2
85·28	1	,,	,,	649·9
85·05	1	,,	,,	651·4
84·70	1n	,,	,,	655·6
84·43	1n	,,	,,	658·9
83·87	1n	,,	,,	665·7
83·50	1n	,,	,,	670·1
83·00	1	,,	,,	676·1
82·82	1	,,	,,	678·3
82·00	1n	,,	,,	688·1
81·67	1	,,	,,	692·2
81·1	1n	,,	,,	699
80·50	1	,,	,,	706·2
80·28	1	,,	,,	708·7
80·00	1	,,	,,	712·2
79·70	1	,,	,,	715·8
78·95	1n	,,	,,	724·9
78·3	1b	,,	,,	723
77·86	1	,,	,,	738·0
77·65	1n	,,	,,	740·6
77·10	1	,,	,,	747·2
76·55	1n	,,	,,	753·9
75·9	1b	,,	,,	762
75·24	1	,,	,,	769·7
74·81	1n	,,	,,	774·9
74·16	1	,,	,,	782·8
73·75	1n	,,	,,	787·7
73·60	1n	,,	,,	789·6
73·35	1n	,,	,,	792·6
73·1	1b	,,	10·1	796
72·53	1	,,	,,	802·4
72·15	1	,,	,,	807·0
71·30	1	,,	,,	817·3
71·04	1	,,	,,	820·5
70·80	1n	,,	,,	823·4
70·4	1b	,,	,,	828
69·49	1	,,	,,	839·3
69·00	1	,,	,,	845·2
68·87	1	,,	,,	846·8
68·51	1	,,	,,	851·2
68·20	1n	,,	,,	855·0
67·89	1n	,,	,,	858·7
67.45	1	,,	,,	867·7
67·15	1n	,,	,,	864·1
66·90	1n	,,	,,	870·8
66·47	1	,,	,,	876·0
66·22	1n	,,	,,	879·1
65·73	2	,,	,,	884·0
65·40	1	,,	,,	889·0

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3265·20	1	0·92	10·1	30891·5
64·95	1	0·81	„	894·5
64·70	1	„	„	897·6
64·35	1	„	„	901·8
64·18	1	„	„	903·4
63·65	1n	„	„	910·4
63·28	1	„	„	914·9
62·90	1n	„	„	919·5
62·72	1n	„	„	921·7
62·45	1n	„	„	925·0
61·8	1b	„	„	934
61·31	1	„	„	938·9
60·86	1	„	„	944·4
60·53	1	„	„	948·5
59·85	2	„	„	956·8
59·36	1	„	„	962·8
58·95	2	„	„	967·8
58·40	1n	„	„	974·5
58·25	1n	„	„	976·4
57·53	1n	„	„	985·2
57·15	1n	„	„	987·8
56·63	1	„	„	996·2
56·30	1n	„	„	35000·2
56·05	1	„	„	003·3
55·67	1	„	„	008·0
55·00	1	„	„	016·1
54·55	1	„	„	021·7
54·30	1	„	„	024·8
53·90	1d	„	„	030·7
53·60	1	„	„	033·3
53·50	1	„	„	034·6
53·07	1	„	„	034·9
52·83	1	„	„	042·8
52·50	1	„	„	046·9
52·20*	1	„	„	050·5
51·90	1	„	„	054·2
51·35	1n	„	„	061·0
50·95	1	„	„	065·9
50·57	1	„	„	070·6
50·0	1n	„	„	078
49·8	1n	„	„	080
49·55	1	„	„	078·2
49·26	1	„	„	086·8
49·00	1	„	„	089·9
48·75	1n	„	„	093·0
48·35	1	„	10·2	097·8
48·12	1	„	„	100·7
47·83	1	„	„	104·3
47·50	1n	„	„	108·3
46·95	1	„	„	114·8
46·70	1	„	„	118·2
46·44	1	„	„	121·4
46·21	1	„	„	124·2

* Mg ?

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3246·00	1	0·81	10·2	35126·8
45·70	1n	,,	,,	130·5
45·43	1n	,,	,,	133·9
45·10	1	,,	,,	138·0
44·78	1	,,	,,	141·9
44·60	1n	,,	,,	144·1
43·95	1n	,,	,,	152·2
42·98	1	,,	,,	164·2
42·60	1	,,	,,	168·8
42·30	1	,,	,,	172·6
42·20	1	,,	,,	173·8
41·48	1	,,	,,	182·8
41·25	1	,,	,,	185·6
40·78	1	,,	,,	191·4
40·60	1	,,	,,	193·7
40·00	1	,,	,,	201·1
39·2	1b	,,	,,	211·0
38·73	1	,,	,,	216·8
38·40	1n	,,	,,	220·9
38·10	1	,,	,,	224·6
37·86	1	,,	,,	227·7
37·40	1	,,	,,	233·3
37·31	1	,,	,,	234·5
37·00	2	,,	,,	238·3
36·1	1nd	,,	,,	248·5
35·88	1	,,	,,	252·3
35·68	1	,,	,,	254·8
34·82	1	,,	,,	265·5
34·70	1	,,	,,	266·9
34·2	1b	,,	,,	273
33·90	1	,,	,,	276·9
33·35	1n	,,	,,	283·7
32·75	1	,,	,,	291·2
32·53	1	,,	,,	293·9
32·16	2	,,	,,	298·5
31·7	1b	,,	,,	304
31·05	1n	,,	,,	312·4
30·5	1n	,,	,,	319
29·96	1n	,,	,,	326·0
29·4	1b	,,	,,	333
29·00	1	,,	,,	338·0
28·1	1b	,,	,,	349
27·90	1n	,,	,,	351·7
27·47	1	,,	,,	357·1
27·05	1	,,	,,	362·4
26·77	1	,,	,,	365·9
26·60	1	,,	,,	368·0
26·28	1	,,	,,	372·0
25·90	1	,,	,,	376·7
25·65	1	,,	,,	379·9
25·5	1n	,,	,,	382
24·95	1	0·80	,,	388·7
24·70	1	,,	,,	391·8
24·45	1	,,	,,	394·9
23·65	1	,,	10·3	404·9

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3223·24	1	0·80	10·3	35410·0
22·80	1	„	„	415·5
22·63	1	„	„	417·7
22·27	1	„	„	422·2
22·08	1	„	„	426·6
21·48	1	„	„	432·1
21·20	2	„	„	435·6
20·75	1n	„	„	441·3
20·57	1	„	„	443·5
20·34	1	„	„	446·4
19·89	1	„	„	452·1
19·26	1n	„	„	460·0
19·06	1	„	„	461·5
18·85	1	„	„	465·2
18·70	1	„	„	467·0
18·43	1	„	„	470·5
18·05	2	„	„	475·2
17·75	1	„	„	479·0
17·3	1b	„	„	485
17·00	1	„	„	488·5
16·88	1	„	„	490·0
16·52	1	„	„	494·5
16·15	1n	„	„	499·2
16·05	1n	„	„	500·4
15·85	1	„	„	503·0
15·30	1	„	„	509·9
15·18	1	„	„	511·4
14·90	1	„	„	514·9
14·73	1n	„	„	517·1
14·12	1n	„	„	524·8
13·9	1n	„	„	527·5
13·7	1n	„	„	529
13·4	1n	„	„	534
13·10	1	„	„	537·6
12·8	1b	„	„	542
12·32	1n	„	„	547·5
11·8	1n	„	„	554
11·49	1	„	„	558·0
11·2	1n	„	„	562
10·87	1n	„	„	565·9
10·50	1	„	„	570·6
10·05	1	„	„	576·3
09·70	1	„	„	580·7
09·08	1	„	„	588·5
08·66	1	„	„	593·9
08·50	1	„	„	595·9
07·20	1	„	„	612·4
06·80	1	„	„	617·5
06·4	1nd	„	„	622·5
05·79	1	„	„	630·3
05·33	1	„	„	636·1
04·10	1	„	„	651·7
03·90	1	„	„	654·3
03·07	1	„	„	664·9
02·65	2	„	„	670·2

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3202·30	1	0·80	10·3	35674·2
01·75	1	,,	,,	681·7
01·43	1	,,	,,	685·8
00·93	1	,,	,,	692·1
00·42	1n	,,	,,	698·6
00·22	1n	,,	,,	701·2
2799·8	1b	,,	,,	706·5
99·2	1b	,,	10·4	714
98·28	1	,,	,,	725·8
97·87	1	,,	,,	731·1
97·45	1n	,,	,,	736·4
97·25	1n	,,	,,	739·0
96·80	1	,,	,,	744·7
96·1	1b	,,	,,	754
95·65*	1	,,	,,	759·5
95·30	2	,,	,,	763·9
95·00	1	,,	,,	767·8
94·50	1n	,,	,,	774·1
94·05	2	,,	,,	779·9
93·54	1	,,	,,	786·5
92·15	1n	,,	,,	804·3
91·4	1n	,,	,,	814
91·16	1	,,	,,	817·0
90·78	1n	,,	,,	821·9
90·4	1b	,,	,,	827
89·9	1b	,,	,,	833
89·2	1b	,,	,,	842
88·7	1b	,,	,,	849
88·24	1	,,	,,	854·5
87·45	1	,,	,,	864·7
86·9	1b	,,	,,	872
86·27	1n	,,	,,	879·9
86·0	1n	,,	,,	883
85·76	1n	,,	,,	886·5
85·50	1	,,	,,	889·7
85·30	1	,,	,,	892·4
85·02	1	,,	,,	896·0
84·77	1	,,	,,	899·2
84·57	1	,,	,,	901·8
84·12	1	,,	,,	907·8
83·99	1	0·79	,,	909·4
83·55	1n	,,	,,	915·0
83·33	1n	,,	,,	917·8
82·52	1n	,,	,,	928·3
82·22	1	,,	,,	932·1
81·90	1	,,	,,	936·2
81·67	1	,,	,,	939·2
81·52	1	,,	,,	941·2
81·16	1	,,	,,	945·8
80·89	1n	,,	,,	949·3
80·13	1	,,	,,	959·1
79·53	1n	,,	,,	966·9
79·05	1n	,,	,,	973·1

* Mg ?

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2778·35	1	0·79	10·4	35982·2
77·27	1	,,	,,	998·1
76·66	1	,,	,,	36004·1
76·45	1n	,,	,,	006·8
75·95	1n	,,	,,	013·3
75·60	1	,,	10·5	017·8
75·50	1	,,	,,	019·1
75·37	1	,,	,,	020·9
75·16	1	,,	,,	023·5
74·88	1	,,	,,	027·1
74·54	1	,,	,,	031·5
74·25	1	,,	,,	035·3
73·90	1	,,	,,	039·8
73·74	1	,,	,,	042·0
73·20	1	,,	,,	048·9
72·75	1	,,	,,	054·8
72·45	1	,,	,,	058·7
72·33	1	,,	,,	060·3
72·02	1	,,	,,	064·3
71·69	1	,,	,,	068·6
71·35	1n	,,	,,	072·9
70·85	1	,,	,,	079·5
70·41	1	,,	,,	085·3
70·15	1	,,	,,	088·6
69·56	1	,,	,,	096·3
69·40	1	,,	,,	098·4
69·17	1	,,	,,	101·4
68·95	1	,,	,,	104·3
68·53	1	,,	,,	109·8
68·30	1	,,	,,	113·9
67·85	1	,,	,,	118·7
67·52	1n	,,	,,	122·9
66·97	1	,,	,,	130·1
66·26	1	,,	,,	139·4
66·00	1	,,	,,	142·8
65·78	1	,,	,,	145·7
65·50	1	,,	,,	149·1
65·3	1br	,,	,,	153
64·80	1	,,	,,	158·5
64·35	1	,,	,,	164·4
63·82	1n	,,	,,	171·4
63·57	1	,,	,,	174·6
62·98	1	,,	,,	182·3
62·50	1n	,,	,,	188·6
61·90	1d	,,	,,	196·4
61·55	1	,,	,,	201·1
61·33	1	,,	,,	203·9
60·46	1	,,	,,	215·4
59·90	1	,,	,,	222·7
59·05	1	,,	,,	233·9
58·62	1	,,	,,	239·5
58·53	1	,,	,,	240·7
58·26	1	,,	,,	244·3
58·03	1	,,	,,	246·3
57·93	1	,,	,,	248·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2757·65	1	0·79	10·5	36252·3
57·40	1	,,	,,	255·5
57·25	1	,,	,,	257·5
56·40	1	,,	,,	268·7
55.26	1	,,	,,	283·7
55·06	1	,,	,,	286·3
54·70	1d	,,	,,	291·0
54·27	2	,,	,,	296·8
53·87	1	,,	,,	301·8
53·52	1	,,	,,	306·7
53·42	1	,,	,,	308·0
53·09	1	,,	,,	312·3
52·57	1	,,	,,	319·2
52·03	2	,,	,,	326·3
51·32	1	,,	10·6	335·6
50·95	1	,,	,,	340·5
50·69	1	,,	,,	343·9
50·50	1	,,	,,	346·5
50·23	1	,,	,,	350·0
50·05	1	,,	,,	352·4
48·98	1	,,	,,	366·5
48·60	1	,,	,,	371·6
48·03	1	,,	,,	379·1
47·47	1	,,	,,	386·5
47·26	1	,,	,,	389·3
46·82	1	,,	,,	395·1
46·27	1	,,	,,	402·4
45·99	1	,,	,,	406·1
45·22	1	,,	,,	416·3
44·95	1	,,	,,	419·9
44·50	1	,,	,,	425·9
44·38	1	,,	,,	427·5
43·79	1	,,	,,	435·4
43·50	2	,,	,,	439·2
43·32	1	,,	,,	441·6
42·70	1	,,	,,	449·8
42·18	1	,,	,,	456·7
41·88	1	0·78	,,	460·8
41·70	1	,,	,,	463·1
41·34	1	,,	,,	467·9
41·19	1	,,	,,	469·9
40·94	1	,,	,,	473·2
40·63	1	,,	,,	477·4
40·40	1	,,	,,	480·4
39·50	1	,,	,,	492·4
39·08	1	,,	,,	498·0
38·65	1	,,	,,	503·8
38·50	1	,,	,,	505·8
38·23	1	,,	,,	509·3
37·93	1	,,	,,	513·3
37·75	1	,,	,,	515·7
37·19	1	,,	,,	523·2
36·45	1	,,	,,	533·1
36·10	1	,,	,,	537·8
35·86	1	,,		541·0

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2735·65	1	0·78	10·6	36543·8
35·42	1	,,	,,	546·9
35·05	1	,,	,,	551·8
34·80	1	,,	,,	555·1
34·34	1	,,	,,	561·3
34·04	1	,,	,,	565·3
33·85	1n	,,	,,	567·8
33·41	1n	,,	,,	573·8
33·06	1	,,	,,	578·4
32·60	1br	,,	,,	584·6
32·15	1n	,,	,,	590·6
31·52	1	,,	,,	599·1
31·38	1	,,	,,	600·9
30·90	1n	,,	,,	606·2
30·43	1	,,	,,	613·7
30·20	1	,,	,,	616·7
29·75	1d	,,	,,	622·8
29·35	1	,,	,,	628·2
29·15	1	,,	,,	630·9
28·8	1n	,,	,,	635·5
28·65	1n	,,	,,	637·6
28·3	1br	,,	,,	642
27·65	1	,,	,,	651·0
27·40	1	,,	,,	654·3
26·75	1n	,,	10·7	663·1
26·61	1	,,	,,	664·9
26·01	1	,,	,,	673·0
25·78	1	,,	,,	676·1
25·56	1	,,	,,	679·0
25·14	1	,,	,,	684·7
24·55	1n	,,	,,	692·6
24·2	1br	,,	,,	697
23·90	1	,,	,,	701·4
23·80	1	,,	,,	702·7
23·43	1	,,	,,	707·7
23·25	1	,,	,,	710·1
22·90	1	,,	,,	714·8
21·95	1n	,,	,,	727·7
21·53	1	,,	,,	734·3
21·25	1	,,	,,	737·1
20·99	1	,,	,,	740·6
20·78	1	,,	,,	743·5
20·50	1	,,	,,	747·2
20·33	1	,,	,,	749·6
20·00	1	,,	,,	754·0
19·63	1	,,	,,	759·1
19·43	1	,,	,,	761·7
19·15	1	,,	,,	765·5
19·00	1	,,	,,	767·5
18·72	1	,,	,,	771·3
18·18	1	,,	,,	778·6
17·65	1	,,	,,	785·8
17·25	1n	,,	,,	791·2
17·10	1n	,,	,,	793·2
16·63	1	,,	,,	799·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2716·48	1	0·78	10·7	36801·6
16·20	1	,,	,,	805·4
16·09	1	,,	,,	806·9
15·66	1	,,	,,	812·8
15·40	1n	,,	,,	816·3
15·10	1	,,	,,	820·3
14·68	1	,,	,,	826·1
14·40	1	,,	,,	829·8
14·04	1	,,	,,	835·7
13·57	2	,,	,,	841·1
13·33	1n	,,	,,	844·4
12·68	1n	,,	,,	853·2
12·20	1	,,	,,	859·8
11·86	1	,,	,,	864·4
11·64	1	,,	,,	867·4
11·23	1	,,	,,	872·7
10·70	1n	,,	,,	880·1
10·20	1n	,,	,,	886·9
09·63	1	,,	,,	894·7
09·12	1	,,	,,	901·7
08·60	1	,,	,,	908·7
08·45	1	,,	,,	910·8
08·05	1	,,	,,	916·2
07·79	1	,,	,,	919·8
07·59	1	,,	,,	922·5
07·09	2	,,	,,	929·3
06·85	1	,,	,,	932·5
06·6	1br	,,	,,	936
06·3	1br	,,	,,	940
05·87	1	,,	,,	946·0
05·33	1	,,	,,	953·4
04·90	2n	,,	,,	959·2
04·2	1br	,,	,,	969
03·83	1n	,,	10·8	973·9
02·9	1br	,,	,,	985
01·95	1	,,	,,	999·5
01·68	1	,,	,,	37003·2
01·50	1	,,	,,	005·6
01·08	1	,,	,,	011·4
00·38	1	,,	,,	021·0
2699·75	1	,,	,,	029·7
99·46	1	0·77	,,	033·7
98·57	2	,,	,,	045·9
98·15	3	,,	,,	051·6
97·52	1	,,	,,	060·2
97·15	1	,,	,,	065·3
96·68	1	,,	,,	071·9
96·40	1	,,	,,	075·8
96·00	1	,,	,,	081·2
95·60	2	,,	,,	096·7
94.35	1	,,	,,	101·2
93·88	2	,,	,,	110·5
93·41	2	,,	,,	116·9
92·49	2	,,	,,	129·5
91·93	1n	,,	,,	137·3

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2691·17	2	0·78	10·8	37147·8
90·65	1	,,	,,	155·0
90·15	1	,,	,,	161·9
89·23	1	,,	,,	174·6
88·76	1	,,	,,	181·1
88·07	1	,,	,,	191·3
87·55	1n	,,	,,	197·8
86·9	1br	,,	,,	207
86·06	2	,,	,,	218·5
85·7	1n	,,	,,	223
84·70	1	,,	,,	237·2
84·40	1	,,	,,	241·5
84·17	1	,,	,,	244·6
83·40	2	,,	,,	255·4
82·40	2n	,,	,,	269·2
81·80	1	,,	,,	277·6
81·23	1n	,,	,,	285·5
80·75	1	,,	,,	292·2
80·3	1n	,,	,,	298·5
80·0	1n	,,	,,	303
79·1	1n	,,	10·9	316
78·96	1	,,	,,	317·1
78·53	1	,,	,,	323·0
78·14	1	,,	,,	328·5
77·68	1	,,	,,	335·0
77·25	1	,,	,,	340·9
76·75	1	,,	,,	347·8
76·50	2	,,	,,	351·3
76·00	1	,,	,,	358·3
75·18	2di	,,	,,	369·8
74·63	1n	,,	,,	377·5
74·10	1n	,,	,,	384 9
73·73	1	,,	,,	390·1
73·51	1	,,	,,	393·1
73·25	1	,,	,,	396·8
72·80	1	,,	,,	403·0
72·38	1	,,	,,	408·9
72·08	1	,,	,,	413·1
71·40	1	,,	,,	423·7
70·99	1	,,	,,	428 4
70·65	1n	,,	,,	433·2
70·50	1n	,,	,,	438·2
69·9	1n	,,	,,	444
69·31	2	,,	,,	452·0
69·02	1	,,	,,	456·0
68·28	1	,,	,,	466·5
68·11	1	,,	,,	468·8
67·25	1n	,,	,,	480·9
66·6	2br	,,	,,	490
65·96	1	,,	,,	499·0
65·76	1	,,	,,	501·9
64·24	2	,,	,,	513·6
63·95	1	,,	,,	527·3
63·5	1br	,,	,,	534

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2663·3*	1br	0·78	10·9	37536·5
62·90	1	,,	,,	542·1
62·2	1br	,,	,,	552
61·27	1	,,	,,	565·2
60·23	1	,,	,,	579·8
60·00	2	,,	,,	583·1
59·60	1	,,	,,	588·7
59·19	1n	,,	,,	594·7
58·85	1	,,	,,	600·2
58·49	1	,,	,,	604·9
58·20	1	,,	,,	608·5
57·96	1	,,	,,	611·9
57·45	1n	,,	,,	619·2
57·25	1n	,,	,,	622·0
56·6	1b	,,	,,	631
55·5	1b	,,	,,	647
55·05	1n	,,	11·0	653·1
54·70	1	0·76	,,	658·0
54·3	1b	,,	,,	664
54·00	1	,,	,,	668·0
53·50	1	,,	,,	675·1
53·20	1	,,	,,	679·3
52·95	2	,,	,,	682·9
52·8	1n	,,	,,	685
52·27	1	,,	,,	692·6
51·96	1	,,	,,	697·0
51·40	1	,,	,,	704·9
50·95	1n	,,	,,	711·3
50·25	1n	,,	,,	721·3
49·65	1	,,	,,	729·8
49·15	2	,,	,,	737·0
48·84	1n	,,	,,	741·4
48·3	1b	,,	,,	749
48·00	1n	,,	,,	753·3
47·65	1n	,,	,,	758·3
47·47	1n	,,	,,	760·9
47·1	1b	,,	,,	766
46·6	1b	,,	,,	773
45·54	2	,,	,,	788·5
44·50	1	,,	,,	803·3
44·22	1	,,	,,	807·3
43·62	1	,,	,,	815·9
43·38	1	,,	,,	819·4
42·9	1n	,,	,,	826
42·00	1	,,	,,	839·1
41·66	1	,,	,,	844·0
41·2	1n	,,	,,	851
40·43	1	,,	,,	861·6
40·00	1	,,	,,	867·8
39·70	1	,,	,,	872·1
39·45	1	,,	,,	875·8
39·10	1	,,	,,	880·7
38·7	1b	,,	,,	886

* Pb ?

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2638·4	1b	0·76	11·0	37891
37·82	1	,,	,,	899·1
37·48	1r	,,	,,	904·0
37·3	1b	,,	,,	907
36·33	1n	,,	,,	920·5
35·91	1	,,	,,	926·6
35·59	2	,,	,,	931·2
35·3	1b	,,	,,	935
34·6	1b	,,	,,	945
34·2	1b	,,	,,	951
33·35	1r	,,	,,	963·4
32·74	1	,,	,,	972·2
32·50	1	,,	,,	975·7
32·08	1	,,	,,	981·8
31·74	1	,,	11·1	986·7
31·42	2	,,	,,	991·3
31·15	2	,,	,,	995·2
30·7	1b	,,	,,	38002
29·95	1n	,,	,,	012·5
29·26	1	,,	,,	022·5
28·99	1	,,	,,	026·4
28·57	1	,,	,,	032·5
28·02	1	,,	,,	040·5
27·62	2	,,	,,	046·3
26·70	1	,,	,,	059·6
25·98	1	,,	,,	070·0
25·30	1	,,	,,	079·9
24·99	1	,,	,,	084·4
23·62	1n	,,	,,	104·3
22·50	1n	,,	,,	120·6
21·86	1n	,,	,,	129·8
21·39	1	,,	,,	136·6
21·08	1	,,	,,	141·1
20·80	1	,,	,,	145·2
20·30	1	,,	,,	152·5
20·18	1	,,	,,	154·3
19·37	1	,,	,,	166·0
18·25	1n	,,	,,	182·4
17·36	1	,,	,,	195·3
16·99	1	,,	,,	200·7
16·13	1	,,	,,	212·6
15·21	1n	,,	,,	226·8
14·0	1n	,,	,,	244
13·35	1n	,,	,,	254·0
13·00	1	,,	,,	259·1
12·52	1	,,	,,	266·2
11·70	1	,,	,,	278·1
11·23	1	,,	,,	285·0
10·75	1*	,,	,,	292·1
10·51	1	,,	,,	295·6
10·01	1	,,	,,	302·9
09·82	1	0·75	,,	305·7
09·34	1	,,	11·2	312·7
09·13	1	,,	,,	313·7
08·62	1	,,	,,	323·3

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2608·25	1	0·75	11·2	38328·8
07·55	1	,,	,,	339·0
06·80	1	,,	,,	350·1
06·60	1	,,	,,	364·1
06·26	1	,,	,,	358·0
05·86	1	,,	,,	363·7
05·48	1	,,	,,	369·5
04·93	1	,,	,,	377·6
04·74	1	,,	,,	380·3
04·37	1	,,	,,	386·0
04·00	1	,,	,,	391·3
03·68	1	,,	,,	396·0
03·50	1	,,	,,	392·0
03·10	1	,,	,,	405·5
02·51	1n	,,	,,	413·3
01·62	2n	,,	,,	426·4
00·9	1b	,,	,,	437
00·4	1b	,,	,,	444
2599·90	1	,,	,,	451·8
98·95	1	,,	,,	465·9
97·77	1	,,	,,	483·4
97·40	1n	,,	,,	488·8
97·10	1n	,,	,,	493·2
96·23	1	,,	,,	506·2
95·71	1	,,	,,	513·9
95·45	1	,,	,,	517·8
95·10	1n	,,	,,	522·9
94·40	1	,,	,,	532·6
93·9	1n	,,	,,	541
93·67	1n	,,	,,	544·3
92·67	1	,,	,,	559·2
92·2	1b	,,	,,	566
91·35	2	,,	,,	578·8
90·90	1	,,	,,	585·4
90·55	1	,,	,,	590·7
90·22	1	,,	,,	595·6
89·70	1	,,	,,	603·3
89·27	1	,,	,,	609·8
89·00	1	,,	,,	613·7
88·65	1n	,,	,,	619·0
87·9	1nd	,,	11·3	630
87·60	1	,,	,,	634·6
87·16	2	,,	,,	641·1
86·33	1	,,	,,	653·5
85·30	1	,,	,,	668·9
84·9	2b	,,	,,	675
84·50	1	,,	,,	680·9
83·5	2b	,,	,,	686
82·72	1	,,	,,	707·6
82·23	1	,,	,,	714·9
81·83	1	,,	,,	720·9
81·22	2	,,	,,	730·1
80·67	1	,,	,,	738·4
79·62	2n	,,	,,	753·6
79·23	1n	,,	,,	760·0

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}$−	
2578·40	1	0·75	11·3	38772·5
77·46	1	,,	,,	786·5
77·14	1	,,	,,	791·4
76·25	1	,,	,,	804·8
75·53	1	,,	,,	815·7
75·3	1n	,,	,,	819
74·8	1b	,,	,,	827
73·3	1n	,,	,,	849
73·04	1n	,,	,,	853·2
72·73	2	,,	,,	857·9
72·43	2	,,	,,	862·5
71·90	1	,,	,,	870·5
71·60	1	,,	,,	874·9
71·16	1	,,	,,	881·7
70·77	1	,,	,,	887·4
70·43	1	,,	,,	892·7
69·85	1	,,	,,	901·5
69·46	1	,,	,,	907·4
68·95	1d	,,	,,	915·1
68·05	1	,,	,,	928·7
67·22	1	,,	11·4	941·3
67·00	1	,,	,,	944·6
66·75	1	,,	,,	948·4
66·00	1	,,	,,	959·8
65·52	2	,,	,,	967·1
64·55	1nd	0·74	,,	981·8
64·02	1n	,,	,,	989·9
63·60	1n	,,	,,	996·5
63·07	1	,,	,,	004·3
62·93	1	,,	,,	006·4
62·68	1	,,	,,	010·3
62·19	1	,,	,,	017·7
61·76	1	,,	,,	024·3
61·03	1	,,	,,	035·4
60·35	1n	,,	,,	045·8
60·10	1	,,	,,	049·6
59·60	1	,,	,,	057·2
59·30	2	,,	,,	061·8
58·43	1n	,,	,,	075·1
58·07	1n	,,	,,	080·6
57·5	1	,,	,,	074
57·1	1	,,	,,	095·2
56·29	2	,,	,,	107·7
55·95	1n	,,	,,	113·0
55·62	1n	,,	,,	118·1
55·27	1n	,,	,,	123·4
54·9	1n	,,	,,	129
54·52	1n	,,	,,	134·9
53·82	1n	,,	,,	145·7
53·53	1n	,,	,,	150·1
52·47	1n	,,	,,	166·3
52·00	1	,,	,,	173·5
51·55	1	,,	,,	180·5
51·2	1n	,,	,,	186
50·9	1nbr	,,	,,	190

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2550·7	1n	0·74	11·4	38193·5
50·1	1n	,,	,,	203
49·43	2	,,	,,	213·1
49·26	1	,,	,,	215·6
48·40	1	,,	11·5	228·8
48·08	1	,,	,,	233·8
47·74	1	,,	,,	239·0
47·47	1	,,	,,	243·2
47·52	1n	,,	,,	242·4
46·45	1n	,,	,,	258·9
46·00	1	,,	,,	39265·8
45·9	1n	,,	,,	281
45·55	1n	,,	,,	272·8
45·12	1	,,	,,	279·4
44·73	1	,,	,,	285·4
44.45	1	,,	,,	289·7
44·12	1	,,	,,	294·8
43·46	1n	,,	,,	305·0
43·30	1n	,,	,,	307·5
42·80	1	,,	,,	315·2
41·95	2	,,	,,	328·4
41·60	1	,,	,,	333·8
41·47	1	,,	,,	335·9
41·14	1	,,	,,	340·9
40·77	1	,,	,,	346·7
40·50	1	,,	,,	350·8
40·40	1	,,	,,	352·4
39·98	1	,,	,,	358·9
39·60	1	,,	,,	364·8
39·38	1	,,	,,	370·2
39·05	1	,,	,,	373·3
38·83	1	,,	,,	376·8
38·51	1	,,	,,	381·7
38·3	1n	,,	,,	385
37·80	1	,,	,,	392·7
37·36	1	,,	,,	399·6
36·88	1	,,	,,	407·0
36·70	1	,,	,,	409·7
36·33	1	,,	,,	415·6
36·00	1	,,	,,	420·7
35·65	2	,,	,,	426·2
35·03	1	,,	,,	435·8
34·95	1	,,	,,	437·0
33·32	1	,,	,,	462·4
33·03	1	,,	,,	466·9
32·80	1n	,,	,,	470·5
32·40	1	,,	,,	476·8
31·88	1	,,	,,	484·9
31·65	1	,,	,,	488·5
31·5	1n	,,	,,	491
30·95	1nd	,,	,,	499·0
30·38	1	,,	,,	508·3
30·14	1	,,	11·6	511·9
29·60	1	,,	,,	520·3
29·06	1	,,	,,	528·8

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2528·83	1	0·74	11·6	39532·5
28·65	1	,,	,,	535·3
28·44	1	,,	,,	538·5
28·17	1	,,	,,	542·7
27·80	1	,,	,,	548·4
27·50	1	,,	,,	553·2
27·23	1	,,	,,	557·5
26·62	1	,,	,,	570·7
26·0	1br	,,	,,	577
25·46	2	,,	,,	585·2
25·02	1	,,	,,	592·0
24·55	1	,,	,,	599·4
24·4	1	,,	,,	602
23·98	1	,,	,,	608·5
23·8	1n	,,	,,	611
23·1	1n	,,	,,	622
22·17	1	,,	,,	636·8
21·9	1	,,	,,	641
21·45	1	,,	,,	648·2
20·99	1	,,	,,	655·4
20·8	1n	,,	,,	658
20·35	1	,,	,,	665·5
19·50	1n	,,	,,	678·7
19·20	1	,,	,,	683·6
19·05	1	,,	,,	685·9
18·56	1	,,	,,	693·8
18·0	1n	,,	,,	702·5
17·27	1n	0·73	,,	714·0
17·06	1n	,,	,,	717·3
16·20	1	,,	,,	730·9
15·80	1	,,	,,	737·2
15·63	1	,,	,,	739·9
15·20	1d	,,	,,	746·7
14·86	1	,,	,,	752·0
14·50	1	,,	,,	757·7
14·17	2	,,	,,	763·0
13·8	1n	,,	,,	769
13·4	1n	,,	,,	775
12·7	1n	,,	,,	786
12·29	1	,,	,,	779·3
12·10	1	,,	,,	779·6
11·05	1n	,,	11·7	812·3
10·97	1	,,	,,	813·5
10·45	1	,,	,,	821·8
10·23	1	,,	,,	825·3
09·60	1n	,,	,,	835·3
09·23	1n	,,	,,	841·2
08·45	1n	,,	,,	853·6
08·02	1	,,	,,	860·4
07·80	1	,,	,,	863·9
07·50	1	,,	,,	868·7
07·18	1	,,	,,	873·7
07·05	1	,,	,,	875·8
06·55	1n	,,	,,	883·8
06·12	1	,,	,,	890·6

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2305·38	1	0·73	11·7	39902·4
04·7	1nd	,,	,,	913
04·0	1nd	,,	,,	924
03·4	1nbr	,,	,,	934
02·5	1n	,,	,,	948
02·00	1	,,	,,	956·3
01·45	1	,,	,,	965·1
00·95	2	,,	,,	973·1
2499·68	2n	,,	,,	993·4
98·90	1	,,	,,	40005·9
98·35	1	,,	,,	014·7
97·85	1	,,	,,	022·7
97·05	2n	,,	,,	035·6
96·13	1n	,,	,,	050·3
95·85	1n	,,	,,	054·8
95·4	1n	,,	,,	062
94·86	1	,,	,,	070·7
94·5	1n	,,	,,	076
94·3	1n	,,	,,	080
93·8	1b	,,	11·8	088
93·00	1	,,	,,	100·5
92·4	1b	,,	,,	110
91·43	1n	,,	,,	125·8
91·03	2	,,	,,	132·2
90·72	1	,,	,,	137·2
89·87	1	,,	,,	150·9
89·33	1	,,	,,	159·7
89·12	1	,,	,,	162·0
88·87	1	,,	,,	167·1
88·63	1	,,	,,	171·0
88·25	1	,,	,,	177·1
87·95	1	,,	,,	181·9
87·70	1	,,	,,	186·0
87·50	1	,,	,,	189·9
87·17	1	,,	,,	194·5
86·83	1	,,	,,	200·0
86·50	1	,,	,,	205·4
86·27	1	,,	,,	209·1
85·85	1	,,	,,	215·9
85·18	1	,,	,,	226·7
85·00	1	,,	,,	229·6
84·72	1	,,	,,	234·2
84·30	1	,,	,,	241·0
84·08	1	,,	,,	244·6
83·88	1	,,	,,	246·8
83·37	1	,,	,,	256·1
83·08	1	,,	,,	260·8
82·75	1	,,	,,	265·6
82·30	1	,,	,,	283·3
82·00	1	,,	,,	278·3
81·60	1n	,,	,,	284·8
81·10	1n	,,	,,	292·9
80·73	1	,,	,,	298·9
80·58	1	,,	,,	301·4
80·25	1	,,	,,	306·7

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2479·67	2	0·73	11·8	40316·1
78·69	3	,,	,,	332·1
78·10	1n	,,	,,	341·7
77·88	1	,,	,,	344·3
77·27	1	,,	,,	355·2
76·56	2	,,	11·9	383·0
75·71	1	,,	,,	380·6
75·40	1	,,	,,	385·6
75·1	1b	,,	,,	390·5
74·26	1	,,	,,	404·2
73·75	1n	,,	,,	412·6
73·46	1	,,	,,	417·3
73·22	1	,,	,,	421·2
72·98	1	,,	,,	425·1
72·82	1	,,	,,	427·8
72·28	1	,,	,,	436·6
71·22	1	,,	,,	454·0
70·93	1	,,	,,	458·7
70·76	1	,,	,,	461·5
70·52	1	,,	,,	465·4
69·67	1	0·72	,,	479·4
69·55	1	,,	,,	481·3
69·23	1	,,	,,	486·6
68·43	1	,,	,,	499·7
68·35	1	,,	,,	501·0
67·98	1	,,	,,	507·1
67·41	1	,,	,,	516·4
66·80	2b	,,	,,	526·4
65·93	1	,,	,,	540·8
65·25	1	,,	,,	551·9
65·01	1	,,	,,	555·9
64·13	1n	,,	,,	570·4
63·87	1n	,,	,,	573·7
63·45	1nd	,,	,,	581·6
62·50	1	,,	,,	597·7
62·40	1	,,	,,	598·9
62·00	1	,,	,,	605·5
61·47	1	,,	,,	614·3
60·95	1n	,,	,,	622·8
60·75	1	,,	,,	626·1
60·4	1n	,,	,,	632
60·22	1	,,	12·0	634·9
59·79	1	,,	,,	641·8
59·30	1	,,	,,	650·0
58·88	2n	,,	,,	657·0
58·4	1n	,,	,,	665
58·03	1	,,	,,	671·0
57·72	1	,,	,,	676·2
57·25	2	,,	,,	684·0
56·30	1	,,	,,	700·1
55·77	1	,,	,,	708·4
55·5	1n	,,	,,	718
55·1	1n	,,	,,	719·5
54·46	2	,,	,,	730·2
53·9	1nd	,,	,,	739·5

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2453·52	1	0·72	12·0	40745·8
52·78	1	,,	,,	758·1
52·21	1	,,	,,	767·5
51·83	1	,,	,,	773·[illegible]
51·20	1	,,	,,	784·3
50·90	1	,,	,,	789·3
50·68	1	,,	,,	793·0
50·51	1	,,	,,	795·8
49·92	1	,,	,,	805·6
49·80	1	,,	,,	817·6
49·55	1	,,	,,	811·6
49·21	1	,,	,,	817·5
48·98	1	,,	,,	821·1
48·61	1	,,	,,	827·5
48·37	1	,,	,,	831·7
47·9	1n	,,	,,	839·3
47·52	1	,,	,,	845·8
46·95	1	,,	,,	855·2
46·60	1nd	,,	,,	861·2
46·22	1	,,	,,	867·4
45·78	1nd	,,	,,	874·7
44·9	1nd	,,	,,	889·5
44·65	1	,,	,,	893·7
44·12	2	,,	,,	902·5
43·60	1	,,	12·1	911·3
42·97	2r	,,	,,	921·6
42·50	1	,,	,,	929·7
42·0	1b	,,	,,	938
41·63	1	,,	,,	944·1
41·40	1	,,	,,	953·0
40·52	1nd	,,	,,	962·8
39·6	1b	,,	,,	978
39·44	1	,,	,,	980·9
39·14	1	,,	,,	986·0
38·60	1	,,	,,	995·1
38·13	1	,,	,,	41002·9
37·75	1n	,,	,,	009·4
37·55	1	,,	,,	012·7
36·70	1	,,	,,	027·1
36·45	1	,,	,,	031·2
35·13	1	,,	,,	053·5
34·84	1	,,	,,	058·4
34·44	1	,,	,,	065·1
33·85	2	,,	,,	075·1
33·37	1	,,	,,	083·2
32·97	1	,,	,,	090·0
32·64	1	,,	,,	095·6
32·41	1	,,	,,	099·4
31·92	1n	,,	,,	107·8
31·7	1n	,,	,,	111
31·35	1	,,	,,	117·5
30·95	1nd	,,	,,	124·2
30·23	1	,,	,,	136·3
29·55	1b	,,	,,	147·9
29·1	1b	,,	,,	155

URANIUM—*continued*.

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2428·53	1	0·72	12·1	41165·1
28·19	1	,,	12·2	170·7
27·73	1	,,	,,	178·6
27·56	1	,,	,,	181·5
27·20	1	,,	,,	187·5
26·65	1	,,	,,	196·9
26·20	1	,,	,,	204·5
25·46	1n	,,	,,	217·1
25·1	1n	,,	,,	223
24·5	1n	,,	,,	230
24·28	1	,,	,,	237·2
23·84	1	,,	,,	244·7
23·35	1n	,,	,,	253·0
23·15	1	,,	,,	256·4
22·7	1b	,,	,,	264
22·0	1b	,,	,,	276
20·6	1b	0·71	,,	300
19·69	1	,,	,,	315·5
18·90	1	,,	,,	328·9
18·44	2	,,	,,	336·8
18·00	1	,,	,,	344·3
17·73	1	,,	,,	349·0
16·85	1n	,,	,,	364·3
16·52	1n	,,	,,	370·7
14·7	1nd	,,	,,	401
14·20	1n	,,	,,	409·4
13·77	1	,,	,,	416·8
13·05	1	,,	,,	429·1
12·60	1	,,	12·3	437·8
12·38	1	,,	,,	440·6
11·97	1	,,	,,	447·6
11·50	1	,,	,,	455·7
10·35	1n	,,	,,	475·5
09·67	1	,,	,,	487·2
09·37	1	,,	,,	492·3
07·67	1	,,	,,	521·7
07·15	1	,,	,,	530·6
06·77	1	,,	,,	537·2
06·54	1	,,	,,	541·2
06·3	1n	,,	,,	545
05·87	1n	,,	,,	552·7
04·51	1	,,	,,	576·2
03·50	2n	,,	,,	593·7
03·00	1n	,,	,,	602·3
02·58	1	,,	,,	609·7
02·28	1	,,	,,	614·8
01·55	1n	,,	,,	627·1
01·4	1n	,,	,,	630·1
01·2	1n	,,	,,	633·5
00·55	1	,,	,,	644·9
00·42	1	,,	,,	647·1
00·09	1	,,	,,	652·8
2399·85	1	,,	,,	657·0
98·65	1n	,,	,,	677·9
97·80	1	,,	12·4	692·5

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2497·45	2	0·71	12·4	41698·6
97·20	2	,,	,,	703·0
96·23	1	,,	,,	719·8
94·14	1	,,	,,	756·2
93·32	1n	,,	,,	770·6
92·8	1n	,,	,,	780
92·4	1n	,,	,,	787
92·1	1n	,,	,,	792
91·68	1n	,,	,,	799·3
91·07	1	,,	,,	809·9
90·80	1	,,	,,	814·6
90·48	1	,,	,,	820·2
90·2	1nb	,,	,,	825
89·33	1	,,	,,	840·4
88·51	1	,,	,,	854·8
87·30	1	,,	,,	875·9
87·0	1nb	,,	,,	881
85·65	1	,,	,,	904·9
85·39	1	,,	,,	909·5
85·18	1	,,	,,	913·2
83·45	1nb	,,	,,	943·6
83·00	1	,,	12·5	951·4
80·8	1n	,,	,,	990
79·85	1	,,	,,	42006·9
78·67	1	,,	,,	027·8
78·24	2	,,	,,	035·4
77·91	2	,,	,,	041·2
77·58	1	,,	,,	047·3
77·05	1	,,	,,	056·5
76·61	1	,,	,,	064·3
76·24	1	,,	,,	070·9
75·92	1	,,	,,	076·5
74·2	1nb	,,	,,	107
73·00	1	0·70	,,	128·2
72·85	1n	,,	,,	131·1
72·0	1n	,,	,,	146
71·6	1n	,,	,,	153
70·96	1	,,	,,	164·5
70·8	1nb	,,	,,	167
70·17	1n	,,	,,	178·6
69·12	1n	,,	,,	197·3
68·50	1n	,,	12·6	208·2
68·2	1nb	,,	,,	214
67·5	1nb	,,	,,	226
67·20	1n	,,	,,	231·4
66·7	1nb	,,	,,	240
66·05	1n	,,	,,	251·9
65·7	1nb	,,	,,	258
65·28	1n	,,	,,	265·7
64·34	1	,,	,,	282·5
64·0	1nb	,,	,,	289
63·50	1	,,	,,	297·4
62·8	1nb	,,	,,	310
62·44	1	,,	,,	316·5
62·1	1nb	,,	,,	323

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2461·53	1	0·70	12·6	41332·9
61·23	1	,,	,,	338·2
60·85	1n	,,	,,	344·7
59·5	1nb	,,	,,	369
58·92	1n	,,	,,	379·7
58·28	1	,,	,,	391·2
58·02	1	,,	,,	395·9
57·67	1	,,	,,	402·2
56·95	1	,,	,,	415·1
56·53	1n	,,	,,	422 7
56·13	1	,,	,,	430·0
55·70	1	,,	,,	437·6
55·40	1n	,,	,,	443·1
55·20	1	,,	,,	446·7
54·83	1	,,	,,	453·4
54·3	1nb	,,	12·7	463
53·6	1nb	,,	,,	475·5
52·9	1nb	,,	,,	488
51·96	2	,,	,,	505·1
50·2	1nb	,,	,,	537
49·97	2	,,	,,	541·0
49·70	2	,,	,,	545·9
49·00	1n	,,	,,	558·6
48·35	1n	,,	,,	570·4
47·6	1nd	,,	,,	584
47·08	1	,,	,,	593·4
46·26	2	,,	,,	608·3
45·50	1n	,,	,,	622·1
45 08	1n	,,	,,	629·8
44·65	1	,,	,,	637·6
44·02	1n	,,	,,	649·1
42·96	1	,,	,,	668·3
42·50	1n	,,	,,	676·7
41·45	2	,,	,,	695·9
40·99	1	,,	12·8	704·1
40·44	1	,,	,,	714·2
38·98	1n	,,	,,	722·6
38·57	1	,,	,,	748·4
38·07	2n (Fe)	,,	,,	757·5
37·01	2	,,	,,	777·0
36·50	1n	,,	,,	786·2
35·88	1n	,,	,,	797·6
35·20	1	,,	,,	810·1
34·37	1n	,,	,,	825·3
33·13	1	,,	,,	849·2
32·65	1	,,	,,	857·0
32·23	1	,,	,,	864·6
31·93	1	,,	,,	870·1
30·28	1	,,	,,	900·5
29·50	1	,,	,,	914·7
29·40	1	,,	,,	916·8
28·95	1	,,	,,	925·0
28·58	1	,,	,,	931·9
28·35	1n	,,	,,	936·1
27·93	1	,,	,,	943·8

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2427·45	1	0·70	12·8	42952·8
27·07	1	,,	12·9	959·6
26·50	2	,,	,,	970·0
25·72	1n	0·69	,,	984·6
25·51	2	,,	,,	988·4
24·90	2	,,	,,	999·7
24·07	1n	,,	,,	3015·2
23·44	1	,,	,,	026·7
21·6	1nb	,,	,,	061
21·1	1nb	,,	,,	070
20·22	1n	,,	,,	085·5
18·51	3	,,	,,	43118·3
18·21	3	,,	,,	123·8
17·9	1n	,,	,,	130
17·6	1n	,,	,,	135
17·2	1nb	,,	,,	143
15·92	1n	,,	,,	166·6
15·07	1n	,,	,,	182·3
14·43	1	,,	,,	194·3
14·22	1	,,	13·0	198·1
13·87	1	,,	,,	204·6
13·23	1	,,	,,	216·6
12·60	2	,,	,,	228·4
11·67	2	,,	,,	245·8
10·71	2	,,	,,	263·7
10·43	2	,,	,,	269·0
09·80	1	,,	,,	280·8
08·80	1n	,,	,,	299·5
08·35	1n	,,	,,	308·0
06·94	2	,,	,,	334·5
05·68	2	,,	,,	358·2
04·46	1	,,	,,	381·1
03·95	1	,,	,,	390·7
03·70	1n	,,	,,	395·4
02·75	1	,,	,,	413·3
01·97	1n	,,	,,	428·1
01·55	1n	,,	,,	436·0
01·0	1nb	,,	13·1	446
00·80	1n	,,	,,	450·0
2299·22	1	,,	,,	479·9
98·41	2	,,	,,	495·2
97·77	1	,,	,,	507·4
97·06	1*	,,	,,	520·8
96·91	2	,,	,,	523·7
96·29	1	,,	,,	535·4
95·93	1	,,	,,	542·2
95·70	1	,,	,,	546·6
95·40	1	,,	,,	552·3
94·93	1	,,	,,	561·2
94·53	1	,,	,,	568·8
93·65	2	,,	,,	585·5
91·69	1	,,	,,	622·8
90·70	1	,,	,,	641·7
90·60	1	,,	,,	643·6
89·33	1	,,	,,	667·8

URANIUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2288·97	1	0·69	13·1	43674·7
88·66	1	,,	,,	680·5
88·35	1	,,	13·2	686·4
87·85	1	,,	,,	696·0
86·82	1	,,	,,	715·6
85·76	1n	,,	,,	735·9
85·23	1n	,,	,,	746·1
84·90	1	,,	,,	752·4
83·80	2	,,	,,	773·5
83·42	1n	,,	,,	780·8
82·85	2	,,	,,	791·7
81·9	1n	,,	,,	810
81·20	1	,,	,,	823·4
81·03	1	,,	,,	826·6
80·20	1	,,	,,	842·6
80·05	1	,,	,,	845·5
79·15	1	,,	,,	862·8
78·7	1n	,,	,,	871·5
78·5	1n	,,	,,	875
78·0	1n	,,	,,	885
77·65	1	0·68	,,	891·7
77·15	1n	,,	,,	901·3
76·80	1n	,,	,,	908·1
76·25	1n	,,	,,	918·7
76·10	2	,,	,,	921·6
75·18	1	,,	13·3	939·3
74·65	1	,,	,,	949·5
74·55	1	,,	,,	951·4
74·15	2	,,	,,	959·2
73·93	1	,,	,,	963·4
73·44	2	,,	,,	972·9
72·73	1	,,	,,	986·6
72·40	1	,,	,,	993·0
71·85	1n	,,	,,	44003·7
70·37	1	,,	,,	032·4
69·8	1nbr	,,	,,	043
68·9	1nb	,,	,,	061
68·55	1n	,,	,,	067·7
67·3	1nbr	,,	,,	092
66·02	2n	,,	,,	116·9
65·50	2n	,,	,,	127·1
64·4	1nb	,,	,,	148·5
63·90	1n	,,	,,	158·3
63·37	1n	,,	13·4	168·3
62·80	1n	,,	,,	179·6
62·45	1n	,,	,,	186·5
61·5	1n	,,	,,	205
59·70	1	,,	,,	240·2
58·00	1n	,,	,,	273·6
54·60	1n	,,	,,	340·4
52·8	1n	,,	,,	376
52·47	1	,,	,,	382·3
51·18	1	,,	,,	407·7
49·93	1	,,	13·5	432·3
49·35	1n	,,	,,	443·8

URANIUM—*continued.*

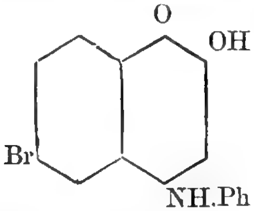
Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2248·83	1	0·68	13·5	44454·1
48·06	2	,,	,,	469·3
47·12	1	,,	,,	487·9
46·34	1	,,	,,	503·4
45·00	1n	,,	,,	529·9
44·40	1n	,,	,,	541·8
44·17	1n	,,	,,	546·4
43·65	1n	,,	,,	556·7
43·45	1n	,,	,,	560·7
42·73	1n	,,	,,	575·0
40·18	1	,,	,,	625·8
69·9	1n	,,	,,	631
38·02	1	,,	13·6	668·8
37·46	2	,,	,,	679·9
36·57	1	,,	,,	695·7
35·88	1n	,,	,,	711·5
34·0	1nb	,,	,,	749
32·88	1n	,,	,,	771·6
32·41	1n	,,	,,	781·0
30·67	1n	,,	,,	816·0
29·6	1nb	0·67	,,	837·5
28·88	1	,,	,,	852·0
28·39	1n	,,	,,	861·8
28·23	1n	,,	,,	865·1
27·95	1n	,,	,,	870·7
27·18	1n	,,	,,	886·2
22·35	1	,,	13·7	983·7
21·5	1nb	,,	,,	45001
19·32	1n	,,	,,	045·1
17·63	1n	,,	,,	079·5
16·15	1n	,,	,,	109·6
15·45	1n	,,	,,	123·9
10·96	1n	,,	13·8	215·4
06·05	1n	,,	,,	316·1
00·80	1	,,	13·9	424·1
2194·85	1	,,	,,	547·3

Isomeric Naphthalene Derivatives.—Report of the Committee, consisting of Professor W. A. TILDEN (*Chairman*) *and* Dr. H. E. ARMSTRONG (*Secretary*). (*Drawn up by the Secretary.*)

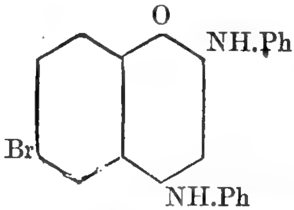
THE investigation of the action of bromine on betanaphthol, referred to in the 1898 Report, has been continued during the past year with the assistance of Mr. W. A. Davis. One of the most important points established is that the nature of the product obtained on tribrominating is largely a question of the conditions. In the presence of a solvent (glacial acetic acid) the tribromonaphthol melting at 155° is the chief product; but if bromine be used alone, and the action take place rapidly at 100°, the isomeric tribromonaphthol (m.p. 159°), described in the 1898 Report, is principally produced. This result is more particularly of interest on account of the fact that the latter compound contains but one, whilst the

former contains two, of its bromine atoms in the hydroxylated ring—which is proved to be the case by their behaviour on oxidation, the tribromonaphthol melting at 159° being convertible into dibromo-, and that melting at 155° into bromo-phthalic acid—so that in the one case the non-hydroxylated ring, and in the other the hydroxylated ring, is attacked.

Unexpected difficulties have been encountered in attempting to determine the position of the second bromine atom in the hydroxylated nucleus of the tribromonaphthol melting at 155°. This compound affords a dibromoquinone isomeric with that produced on decomposing the dibromonitroketo-compound derived from dibromonaphthol. Both these dibromoquinones are converted into 1 : 3 : 4 bromophthalic acid on oxidation. Consequently the one contains a bromine atom in position 3, and the other a bromine atom in position 4. When subjected to the action of aniline, however, both yield the same two anilides.

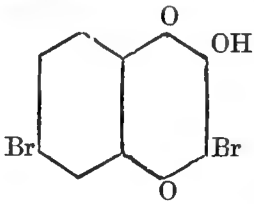


and



Nor have results yet been obtained by means of alkalies which afford a solution of the problem.

The dibromoquinone obtained from the bromonaphthol melting at 155° is remarkably sensitive to oxidation, being slowly converted into the dibromohydroxy-quinone when kept; a result which appears to favour



the view that bromine is present in the tribromonaphthol in position 3. The dibromoquinone in question may be recrystallised from ethylic acetate, but if left too long in contact with the solvent it is converted into an infusible condensation product. This quinone is therefore a compound which it will be desirable to study in detail.

The tribromonaphthol melting at 155° is acted on with difficulty by bromine, remaining for the most part unchanged when its solution in acetic acid is digested with bromine during thirty to forty hours at 100° to 120°, only a small portion being converted into the tetrabromonaphthol melting at 172°, described by Armstrong and Rossiter. The tribromonaphthol melting at 159°, under similar conditions, is without difficulty converted into a tetrabromonaphthol melting at 184°, which is convertible into a tribromoquinone isomeric with that obtainable from the isomeric tetrabromonaphthol. A third tetrabromonaphthol has been obtained in small quantity together with that melting at 184° by acting directly on betanaphthol with dry bromine. It is distinguished by yielding a tetrabromonaphthaquinone.

Both tribromonaphthols are easily reduced at 100° by a saturated

solution of hydrogen iodide, the bromine atom in position 1 being displaced. Two new dibromonaphthols are thus obtained: that from the tribromonaphthol melting at 155° melts at 137° to 138°, and that from the isomeric naphthol melts at 127°. On digesting these dibromonaphthols with alcohol and sulphuric acid under similar conditions that containing one of the bromine atoms in the hydroxylated ring yields only about 55, whilst that containing both bromine atoms in the non-hydroxylated ring yields about 61 per cent. of ether.

A comparison of the behaviour of the various chloro- and bromobetanaphthols towards hydrogen iodide with their behaviour on etherification is of interest as showing that both changes are subject to similar influences; they therefore may be discussed from the same point of view. As the reducing effect is confined to the bromine atom contiguous to the OH group, this alone being displaced by hydrogen, the OH group must be supposed to be concerned in the change. Probably it exercises an attractive influence, and this influence must be regarded as subject to modification by every change in the hydrocarbon radicle, so that reduction takes place less readily just as etherification takes place less readily in the case of the more fully substituted compounds. The etherification of the derivatives of betanaphthol has been discussed by Mr. Davis from this point of view in a paper published in the 'Transactions of the Chemical Society' early in the present year (**77**, 33).

On the Constitution of Camphor. By A. Lapworth, *D.Sc.*

[Ordered by the General Committee to be printed *in extenso.*]

The question of the constitution of camphor has occupied the attention of a large number of chemists for many years, and it still presents opportunities for much speculation. Recently, however, it has come to be fully recognised that the earlier writers on the subject were misled by the ease with which benzenoid compounds could be obtained from many camphor derivatives, and it is now quite clear that the greatest care must be exercised in attributing special significance to evidence based on observations of this kind.

The formation of large quantities of *p*-cymene and carvacrol from camphor by the action of phosphorus pentoxide was the basis of some of these earlier speculations, and to carry the arguments to their logical conclusion it would be necessary to make the formulæ account for the production of *m*-cymene, which is obtained in considerable amount when zinc chloride or phosphorus pentasulphide is the agent,[1] and also of 1 . 2 . 4 . dimethyl ethyl benzene and 1 . 2 . 3 . 5 tetramethylbenzene.[2] The formation of 1 . 3 . 4 acetyldimethylbenzene by the action of sulphuric acid on camphor[3] would also require elucidation.

It appears natural to suppose that, if we are still unable to discover with certainty the principles underlying the changes referred to, we should also be cautious in interpreting the meaning of other transformations which involve any alteration in the structure of closed rings, and it is now pretty generally recognised that the divergence of opinion which still exists with regard to the constitution of the camphor nucleus must be due

[1] Armstrong and Millar, *Ber.* **16**, 2225. [2] *Ibid., loc. cit.*
[3] Armstrong and Kipping, *Trans. Chem. Soc.*, **63**, 75.

to the occurrence of unsuspected intramolecular changes during reactions which are at present deemed susceptible of only one simple interpretation.

In the case of a problem of this kind in which a very large amount of experimental material has to be dealt with, some of which appears to point conclusively to one view and some in an equally unequivocal manner to another, it would appear to be the most logical course to sift the material in such a way that the relative value of the evidence on each side may be compared, and, if possible, so as to gain a clue as to the exact points at which the tendency appears to change, so that particular attention may then be directed to those points.

In the present communication it is proposed first of all to select from the material those facts which bear directly on the points at issue, accepting only those conclusions which no longer reasonably admit of dispute, and then to discuss the significance of the rest of the evidence relating to the still undecided question of the ultimate structure of the camphor molecule.

A.—GENERAL NATURE OF CAMPHOR.

Camphor has the formula $C_{10}H_{16}O$: it is a ketone, as it yields well-defined hydrazones, an oxime and a semicarbazone. It is saturated, and therefore must be considered to consist of two closed carbon rings, of which one includes the carbonyl or ketone group $>CO$.

As it will clearly be of importance to be able to refer to either of these rings, one will afterwards be termed the *ketone* ring, and the other the *hydrocarbon* ring.

B.—PROPERTIES AND TRANSFORMATIONS OF THE KETONE RING.

1. The Ketone Ring contains the Group —CH_2.CO—

That the carbonyl group $>CO$ of camphor is in direct attachment to a methylene group —CH_2— is proved conclusively by the following considerations :—

(a) *Formation of Camphoric Acid by the Oxidation of Camphor.*

When camphor is treated with the usual oxidising agents it is converted into camphoric acid, $C_{10}H_{16}O_4$, a saturated, dicarboxylic acid. This transformation is simply explained only by the assumption that the change proceeds in accordance with the scheme

$$C_8H_{14}\left\langle\begin{array}{l} CH_2 \\ | \\ CO \end{array}\right. \quad \rightarrow \quad C_8H_{14}\left\langle\begin{array}{l} COOH \\ \\ COOH \end{array}\right.$$

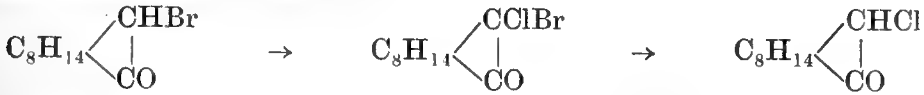
Camphor. Camphoric Acid.

(b) *Formation and Properties of the simplest Substitution Derivatives of Camphor.*

(i) *Halogen and Nitro-compounds.*—Camphor ordinarily yields only *mono-* and *di*-substitution derivatives (termed α-derivatives) on treatment with the characteristic substituting agent such as the halogen or nitric acid, and with aliphatic saturated ketones the position of substitution is at the carbon atom contiguous to the carboxyl group.

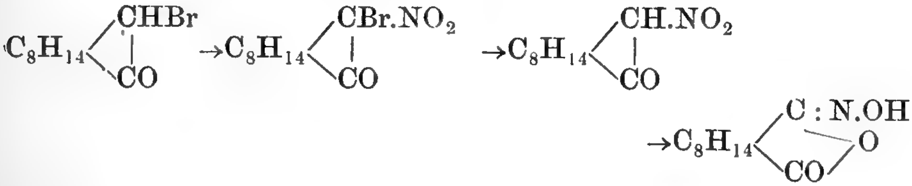
The α-mono-halogen derivatives, such as α-monobromocamphor, on treatment with oxidising agent are converted into camphoric acid

The α-di-derivatives are only oxidised with great difficulty, and on treatment with alkalis are usually converted into the α-*mono*-derivatives. Thus when α-bromocamphor is chlorinated it yields a mixture of two stereoisomeric bromochlorocamphors, both of which are converted into α-chlorocamphor on treatment with alkali, so that both halogen atoms must be attached to the same carbon atom [1]

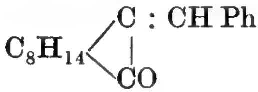


α-Bromocamphor. $\alpha\alpha$-Bromochlorocamphor. α-Chlorocamphor.

Again the α-monohalogen derivatives when heated with nitric acid are converted into nitroderivatives, which yield α-nitrocamphor on treatment with alkali ; nitrocamphor when heated with acids is converted into the oxime of camphoric anhydride. Moreover the α-nitrocamphors exist in tautomeric forms, characteristic of nitrocompounds containing the group $>CH.NO_2$.[2]

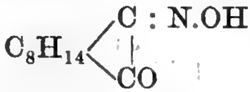
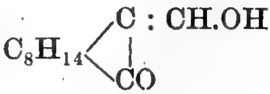


(ii) *Camphor yields Alkylidene Derivatives on Treatment with Aldehydes.*—When camphor is acted on by, for example, benzaldehyde, in presence of sodium, condensation occurs, and a benzylidene camphor is finally obtained. Its constitution must be expressed by the formula



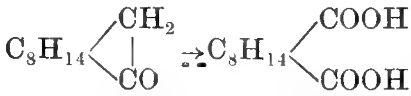
as only ketones containing the group $—CH_2.CO—$ are known to react in this way.

(iii) *Camphor is capable of taking part in the Claisen Reaction.*—The Claisen condensation, which is capable of application among saturated ketones only to those containing the group $—CH_2 . CO—$, is applicable to camphor under certain conditions, and isonitro-, and hydroxy-methylene camphor, &c. are readily obtained. These can only be expressed by the formulæ

 and 

[1] Lowry, *Trans. Chem. Soc.*, **73**, 569.
[2] *Ibid.*, **73**, 986.

2. The Relation between Camphor and Camphoric Acid is in reality the simple one expressed by the Scheme

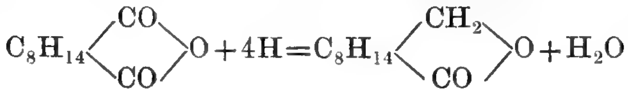


It has been usual in discussing the relationship between these two substances to dismiss the subject with a few words, but the point requires much more careful consideration and proof than it is usually deemed worthy of, and it cannot be insisted too frequently that in dealing with the mutations of closed-chain compounds, such as the derivatives of camphor, such transformations should be regarded from all points of view, especially, as in the present instance, where the evidence derived from the different fields of work cannot be viewed in its entirety until the point is decided beyond all doubt.

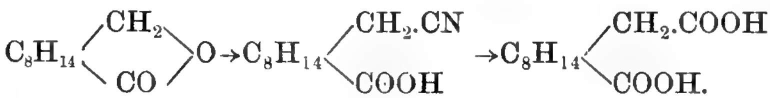
In the case in question, fortunately, there is no doubt whatever that the ordinary view is the correct one, as, besides the various modes in which it is possible to pass from camphor to camphoric acid, which have already been referred to, the relationship has been established by a series of simple changes which render it possible to traverse the ground in the reverse direction. The evidence is as follows :[1]—

(a) *Camphoric Acid readily yields Homocamphoric Acid.*

When camphoric anhydride is treated with sodium amalgam under suitable conditions, it is reduced to a lactone, campholide, as follows :—

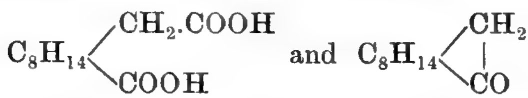


and campholide when heated with potassium cyanide yields cyanocampholic acid, from which homocamphoric acid is easily obtained on hydrolysis. The changes are of the following kind :—



Campholide. Cyanocampholic Acid. Homocamphoric Acid.

(b) *Homocamphoric Acid and Camphor are related to one another in the following way :*



and the evidence on which this statement is based is twofold.

α-Cyanocamphor yields Homocamphoric Acid on Hydrolysis.—Cyanocamphor, a product of the action of cyanogen or cyanogen bromide

[1] Haller, *Compt. Rend.*, **122**, 446.

on sodium camphor, or of the dehydration of the oxime of α-camphoraldehyde, must necessarily be an α-derivative.

$$C_8H_{14}\left<\begin{array}{l}CHNa\\ |\\ CO\end{array}\right. + Br.CN = C_8H_{14}\left<\begin{array}{l}CH.CN\\ |\\ CO\end{array}\right. + NaBr$$

$$C_8H_{14}\left<\begin{array}{l}CH.CH:N.OH\\ |\\ CO\end{array}\right. - H_2O = C_8H_{14}\left<\begin{array}{l}CH.CN\\ |\\ CO\end{array}\right.$$

and when this compound is boiled with alkalis it suffers hydrolysis in two senses, being converted into ammonia and homocamphoric acid.[1]

$$C_8H_{14}\left<\begin{array}{l}CH.CN\\ |\\ CO\end{array}\right. + 3H_2O = C_8H_{14}\left<\begin{array}{l}CH_2.COOH\\ \\ COOH\end{array}\right. + NH_3$$

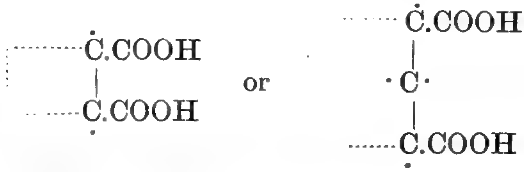
(c) *Camphor may be regenerated from Homocamphoric Acid.*

When the barium salt of homocamphoric acid is subjected to dry distillation it is broken up into barium carbonate and camphor, a change which must be expressed by the equation

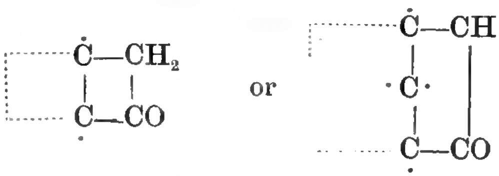
$$C_8H_{14}\left<\begin{array}{l}CH_2.CO.O\\ \\ CO.O\end{array}\right>Ba = C_8H_{14}\left<\begin{array}{l}CH\\ |\\ CO\end{array}\right. + BaCO_3.^2$$

3. THE KETONE RING IS EITHER A 4- OR A 5-CARBON RING.

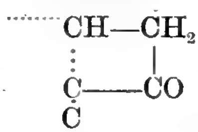
Since camphoric acid very readily affords an anhydride on treatment with acetyl chloride, even in the cold, it follows that it must be a derivative of succinic or of glutaric acid, so that it may be represented by one of the formulæ



Hence camphor has the corresponding structure



C.—CAMPHOR CONTAINS THE GROUP



[1] Haller, *Dissertation*, Nancy, 1879.
[2] Haller, *Compt. Rend.*, 122, 446; and Baeyer, *Ann.*, **289**, 6.

In support of this conclusion there may be advanced a number of well-established facts, and the necessity for the discussion of the points involved may be made the occasion for introducing the nomenclature necessary for reference to the derivative of camphoric acid.

1. Camphor Acid contains only one Hydrogen Atom in the α-Position with regard to a Carboxyl Group.

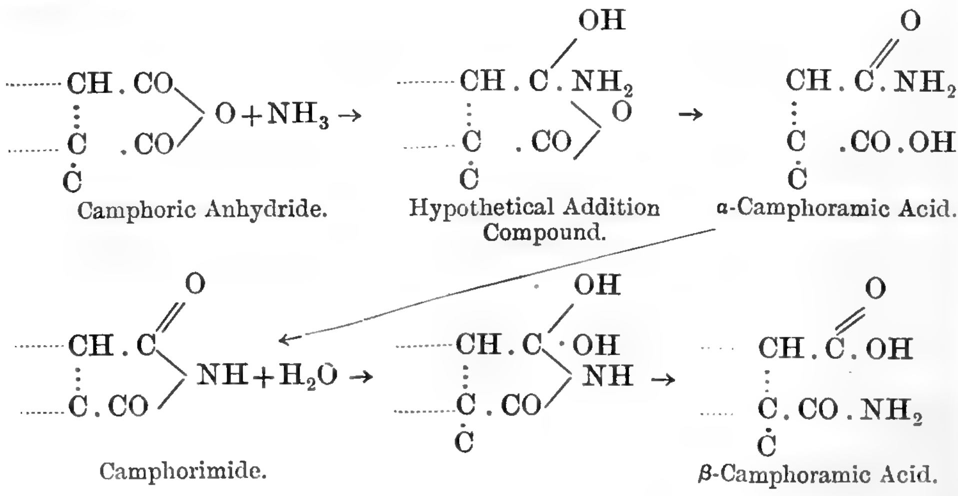
(a) *Bromination of Camphoric Acid.*

Camphoric acid is capable of affording, by direct bromination, one, and only one, monobromo-derivative, ω-bromocamphoric acid. From the study of a very large number of acids it has been ascertained that it is possible to introduce as many bromine atoms as there are hydrogen atoms in the α-position with regard to carboxyl groups, and in each case where the products have been completely investigated it has been shown that the entrant bromine atoms occupy the α-position. The conclusion thus derived regarding camphoric acid is confirmed by a large number of observations, and there is no sufficient reason to imagine that the bromination of camphoric acid pursues any but the normal course.

(b) *Differential Reactivity of the two Carboxyl Groups.*

Camphoric anhydride on treatment with ammonia yields exclusively, or almost exclusively, α-camphoramic acid. This on distillation loses water, yielding camphorimide, which when subjected to alkaline hydrolysis affords only β-camphoramic acid.

The reactivity of carboxyl or carboxyl groups in aliphatic compounds invariably appears great or small according as the adjacent carbon atom is hydrogenised or not. The above observations, which show that there is an enormous difference between the reactivity of the carboxyl groups in the anhydro-camphoric derivatives, are doubtless accounted for by the fact that only one of the two carboxyl groups of camphoric acid is an attachment to a hydrogenised carbon atom. On this assumption the course of the changes referred to may probably be expressed as follows :—

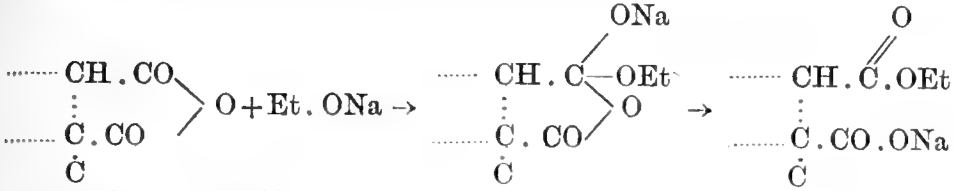


Camphoric Anhydride. Hypothetical Addition Compound. α-Camphoramic Acid.

Camphorimide. β-Camphoramic Acid.

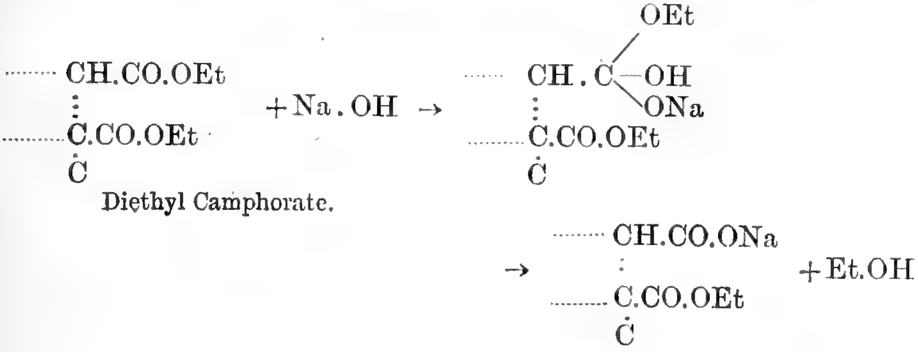
Camphoric acid also yields two series of alkyl hydrogen esters, which have been obtained in the following way :—

Camphoric anhydride when treated with sodium ethoxide yields the sodium salt of *ortho*-ethyl hydrogen camphorate



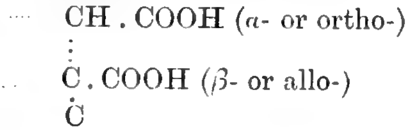
Camphoric Anhydride. *ortho*-Ethyl Hydrogen Camphorate.

Diethyl camphorate when hydrolysed with soda, however, affords the sodium salt of *allo*-ethyl hydrogen camphorate.



Diethyl Camphorate. *allo*-Ethyl Hydrogen Camphorate.

The carboxyl groups of camphoric acid have therefore been referred to in two different ways, namely—



The above inferences regarding the constitution of the two camphoramic acids and the two ethyl hydrogen camphorates receive confirmation in the behaviour of the former on treatment with hypobromite (compare E. 2. c.), and of the latter when subjected to electrolysis (compare E. 2. a.).

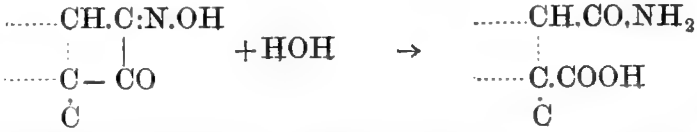
(c) *The β- or Allo-carboxyl Group of Camphoric Acid represents the Carbonyl Group of Camphor.*

Whilst the facts on which this conclusion depends are few in number, they are such as to render their interpretation simple and beyond question. The following may be mentioned here.

When isonitrosocamphor is warmed with hydrochloric acid it is converted into α-camphoramic acid,[1] and, in accordance with the con-

[1] Claisen and Manasse, *Ann.*, **274**, 73

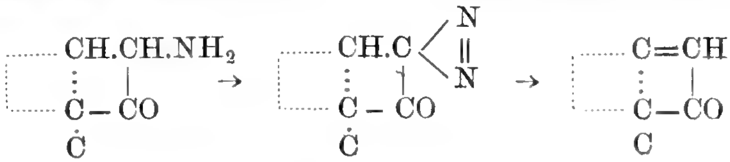
stitution of the latter compound (C. 1. b.), the change can only be written as follows ;—



Lowry's observation that α-nitrocamphor yields the same camphoryloxime as is obtained directly from camphoric anhydride by treatment with hydroxylamine leads to the same conclusion (compare B. 1. b. i.).

2. Formation of Camphenone.

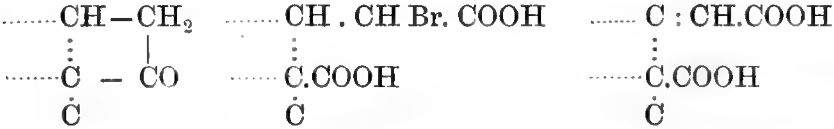
When α-aminocamphor is treated with nitrous acid it is converted into diazocamphor, which loses nitrogen when heated and yields considerable quantities of camphenone, $C_{10}H_{14}O$, which has all the properties of an unsaturated ketone.[1]



Aminocamphor. Diazocamphor. Camphenone.

3. Formation of Dehydrohomocamphoric Acid.

When homocamphoric acid is brominated it yields a monobromo-derivative, α-bromohomocamphoric acid. When the diethyl-ester of this monobromo acid is heated with quinoline and then with alcoholic potash it loses hydrogen bromide, affording dehydrohomocamphoric acid, which is certainly an $\alpha\beta$-unsaturated acid. Taking into consideration the relationship subsisting between camphor and homocamphoric acid, this fact is readily explained by the assumption comprised by C, and it may be added that its behaviour on oxidation is only explicable by the aid of that view (compare E. 3.).



Camphor. α-Bromohomocamphoric Acid. Dehydrohomocamphoric Acid.

D.—CAMPHOR AND CAMPHORIC ACID CONTAIN TWO NON-EQUIVALENT ASYMMETRIC CARBON ATOMS.

Camphor and camphoric acid are optically active, and therefore contain at least one asymmetric carbon atom. Whilst the former is only known in two enantiomorphous forms and their externally compensated inactive combinations, the latter is known to exist in six forms, of which two pairs are enantiomorphously related, and the other two forms are externally compensated mixtures of the other pairs.

[1] Angeli, *Gazzetta*, **23** [2], 351.

The six forms of camphoric acid are completely explained on the assumption that in the molecule there are two asymmetric carbon atoms which are not equivalent. Designating the two carbon atoms by the letters A and B, the six forms may be represented by the combinations, no internally compensated form being possible :

(A_dB_d) and (A_lB_l)...*d*- and *l*-camphoric acid.
(A_dB_d) and (A_dB_l)...*d*- and *l*-isocamphoric acid.
$(A_dB_d+A_lB_l)$...Inactive camphoric acid.
$(A_lB_d+A_dB_l)$...Inactive isocamphoric acid.[1]

It does not appear that the sign of both asymmetric carbon atoms can be reversed by simple means, but *d*-isocamphoric acid may be obtained from *d*-camphoric acid fairly readily ; as, for example, by treatment with phosphorus pentachloride and water successively, whilst the reverse change may also be effected by suitable means, such as boiling with acetyl chloride, or by the process of bromination, when ordinary bromocamphoric-anhydride is obtained.

The readiness with which one of these asymmetric carbon atoms is affected makes it seem certain that this must be the atom on which a carboxyl group and a hydrogen atom are attached, as there is here the only grouping where the existence of tautomerism, or simple internal change, appears possible. A glance at the simple scheme for camphoric acid, moreover,

CH.COOH
⋮
C.COOH
Ċ

makes it appear highly probable that each carboxyl group is an attachment to one or other asymmetric atom, and the difficulty of conceiving any simple internal change which would affect the condition of the second asymmetric atom accounts sufficiently well for the non-occurrence of inversion in this instance.

The occurrence of only two enantiomorphously related camphors is probably dependent on stereochemical considerations, analogous to the non-formation of anhydrides from *trans*-dicarboxylic acids of the polymethylene series.

E.—DEGRADATION OF CAMPHOR DERIVATIVES.

Whilst the material which has already been dealt with affords us much useful evidence regarding the structure of the ketone ring, there is little or none of it which affords us any assistance in coming to any conclusions regarding the hydrocarbon ring. In order to gain any conception as to the structure of the second nucleus it becomes necessary to consider the nature of products which are obtained when this ring is broken down in various ways.

It will be convenient to refer to each of the various modes in turn, and to consider the constitution of the products of known character as they come under consideration.

[1] Aschan, *Acta soc. Sci. fennicæ*, **21**, 1.

1. Oxidation of Camphor and Camphoric Acid.

(a) *Oxidation with Nitric or Chromic Acid.*

When camphor is subjected to prolonged heating with nitric or chromic acid a large number of products are obtained, of which the more important are camphoric acid and its oxidation products, namely, camphanic acid, camphoronic acid, and trimethylsuccinic acid, together with a small quantity of isocamphoronic acid, which is certainly an independent product, as it does not appear to be produced from camphoric acid under any circumstances.

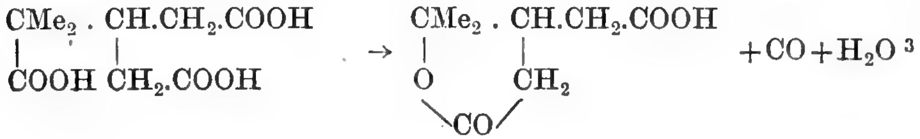
(i.) *Constitution of Camphoronic Acid.*—From a study of the products obtained by the dry distillation of camphoronic acid Bredt was led to the view that this acid had the structure

$$COOH\,.\,CMe_2\,.\,CMe(COOH)\,.\,CH_2\,.\,COOH$$ [1]

and this conclusion has been rendered final by the synthesis of the acid by Perkin and J. F. Thorpe[2] in a manner the course of which admits of only one interpretation.

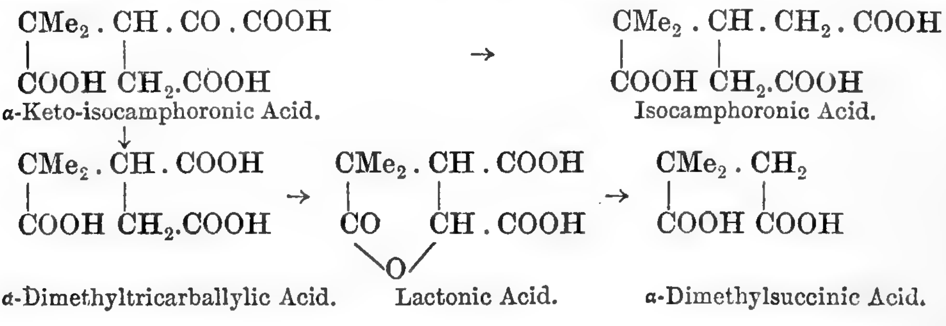
(ii.) *Constitution of Isocamphoronic Acid.*—Isocamphoronic acid has the structure $CMe_2(COOH)\,.\,CH(CH_2\,.\,COOH)_2$, as follows from the following observations :—

When the acid is warmed with sulphuric acid it loses carbon monoxide, and is converted into a lactonic acid of known constitution, namely, terpenylic acid :



Additional support for the formula given is supplied by the following indirect observations :—

α-Keto-isocamphoronic acid, obtained by a series of changes from pinene, yields isocamphoronic acid when reduced, and when oxidised with lead peroxide and acetic acid is converted into α-dimethyltricarballylic acid. The latter acid is not a malonic derivative, and when treated with bromine is converted into the lactone of the hydroxy-acid, which yields α-dimethylsuccinic acid on fusion with potash :

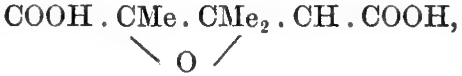


[1] *Ber.*, **26**, 3049. [2] *Trans. Chem. Soc.*, **71**, 1169. [3] Tiemann, *Ber.*, **29**, 2612.

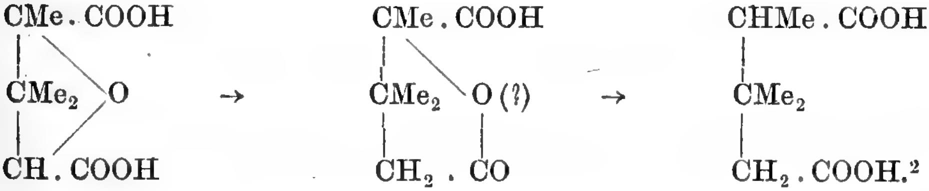
(b) *Oxidation of Camphoric Acid with Dilute Cold Permanganate.*

When camphoric acid, dissolved in the requisite quantity of soda, is allowed to remain with cold dilute potassium permanganate solution for some months, it is converted into a dibasic acid having the formula $C_8H_{12}O_5$ or $C_6H_{10}O\,(COOH)_2$ and oxalic acid, the products being in approximately equivalent amount. This acid yields only additive products with hydroxylamine or hydrazines, so that the fifth oxygen atom does not possess true ketonic functions. On reduction it yields, first, a lactonic acid, $C_8H_{12}O_4$, and then $\alpha\beta\beta$-trimethylglutaric acid.

Balbiano explains the behaviour of the acid $C_8H_{12}O_5$ on the assumption that it is an acid possessing the structure of an oxide derived from a dihydroxy acid



and it is not easy to understand what other view can be taken. The successive stages of its reduction are consequently



2. The Products obtained by eliminating a Carboxyl Group from Camphoric Acid.

(a) *Electrolysis of the Isomeric Ethyl Hydrogen Camphorates.*

When the two isomeric ethyl hydrogen camphorates (compare C. 1. b.) are submitted to electrolysis the products consist for the most part of esters of unsaturated, closed-chain, monobasic acids, produced in accordance with the equation

$$C_8H_{14}{<}{\begin{matrix}COOEt\\COOH\end{matrix}} = CO_2 + H_2 + C_8H_{13}\,.\,COOEt.$$

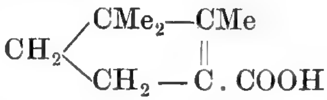
(i.) *Electrolysis of* Ortho-*ethyl Hydrogen Camphorate.*—*Ortho* ethyl camphorate (C. 1. b.) on electrolysis yields mostly the esters of two isomeric acids, namely, campholytic and isolauronolic acids. These two acids are inactive, and are intraconvertible by processes analogous to those whereby fumaric and maleic acids may be converted one into the other.[3]

[1] Balbiano, *Ber.*, **27**, 2133.

[2] Compare also Balbiano, *Ber.*, **28**, 1506; *Atti Lincei*, 1894, i. 278, and ii. 240; *Gazzetta Chim. Ital.*, **26**, 1; and *Ber.*, **30**, 289 and 1901. Also Mahla and Tiemann, *Ber.* **28**, 2151 and 2811.

[3] Walker, *Trans. Chem. Soc.*, **63**, 495, and **67**, 347.

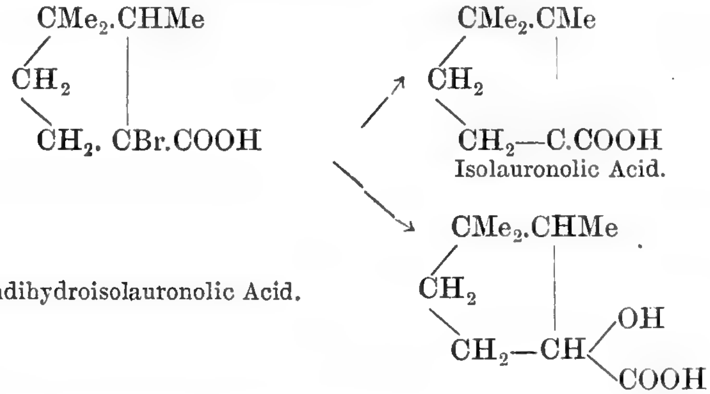
Structure of Isolauronolic Acid.—The structure of this acid is almost certainly represented by the formula



first suggested implicitly by Perkin[1] and independently by Bouveault;[2] and the grounds for this statement are briefly as follows :—

It is inactive, and cannot be separated into active forms. It therefore does not contain an asymmetric carbon atom.

It is an $\alpha\beta$-unsaturated acid, as its dibromide loses carbon dioxide and hydrogen bromide on treatment with soda or sodium carbonate, a behaviour associated almost exclusively with $\alpha\beta$-dibromo acids. Moreover, dihydroisolauronolic acid is readily brominated, as usual in the α-position, and the mono-bromo acid on treatment with alkali affords isolauronolic acid and α-hydroxydihydroisolauronolic acid.[3]

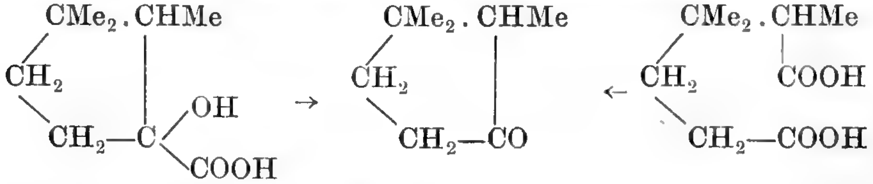


α-Bromdihydroisolauronolic Acid.

Isolauronolic Acid.

α-Hydroxydihydroisolauronolic Acid.

The latter compound when heated with lead peroxide and acetic acid affords a ketone which is identical with $\alpha\beta\beta$-trimethylketopentamethylene, obtained by distilling the barium salt of $\alpha\beta\beta$-trimethyladipic acid.[4]

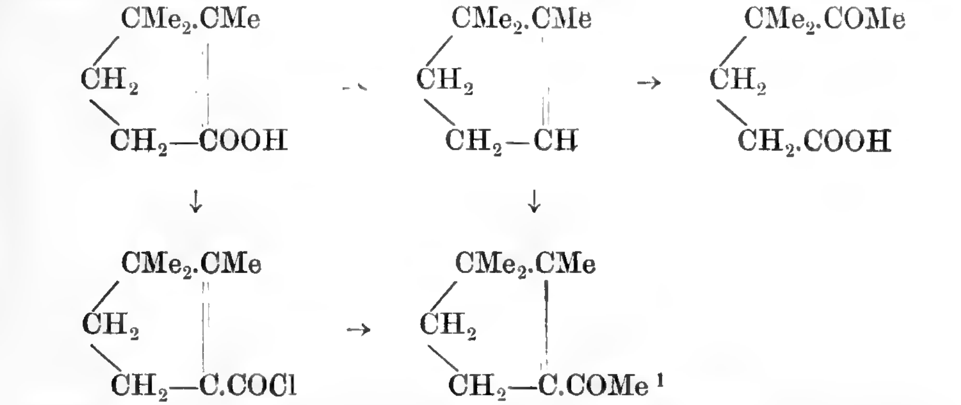


Striking confirmation of the above formula for isolauronolic acid is afforded by the following series of reactions.

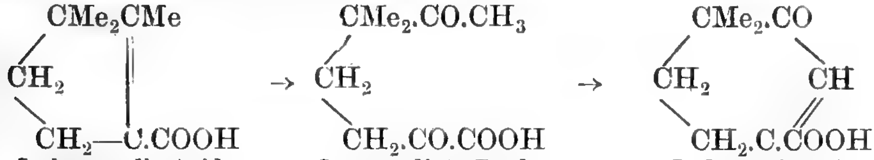
Isolauronolic acid, when heated in closed tubes at 300°, loses carbon dioxide, and is converted into a hydrocarbon, C_8H_{14}, which yields γ-acetyldimethylbutyric acid on oxidation. That the production of the hydro-

[1] *Proc. Chem. Soc.*, 1896, p. 191. [2] *Bull. Soc. Chim.* (iii.), **19**, p. 462.
[3] Noyes, *Ber.*, **29**, 2326 and 1900, and Perkin, *Trans. Chem. Soc.*, **73**, 838.
[4] Noyes, *Ber.*

carbon is not attended with any isomeric change is proved by the fact that it yields, on treatment with acetyl chloride in presence of aluminium chloride, a ketone identical with that obtained by the action of zinc methide on isolauronolic chloride :



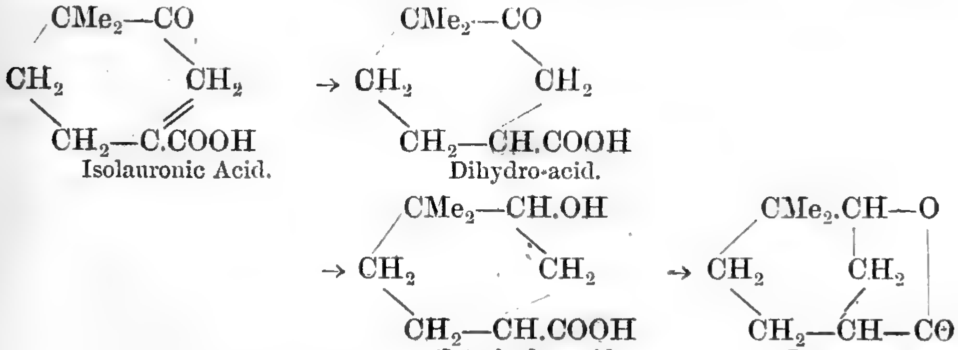
The formation of isolauronic acid, during the oxidation of isolauronolic acid with faintly alkaline permanganate, hitherto so difficult to understand, is easily explained by the use of the foregoing formula, as the first action of the oxidising agent would result in the formation of an acid derived from a 1 : 5-diketone, a class of compounds very prone to undergo condensation in alkaline solution, that is to say, under conditions similar to those in which isolauronic acid arises :[2]



Isolauronolic Acid. Intermediate Product. Isolauronic Acid.

Bouveault's formula for isolauronic acid has been submitted to searching tests by Blanc, with the result that no reasonable doubt of its correctness can any longer be entertained. The following observations are so important as to warrant somewhat detailed description.

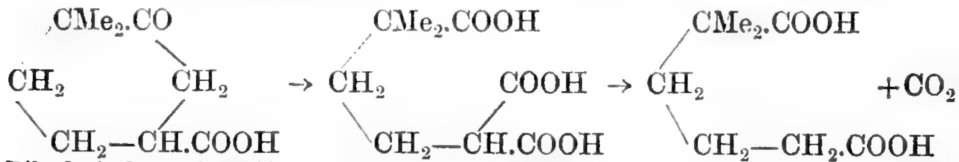
Isolauronic acid is reducible by two stages : first to dihydroisolauronic acid, which is of a ketonic nature ; and secondly to the tetrahydro-acid, which must be a γ or δ-hydroxy acid, as it affords a lactone with great readiness :



Isolauronic Acid. Dihydro-acid. Tetrahydro-acid. Lactone.

[1] Blanc, *Bull. Soc. Chim.* (iii.), **19**, 699.
[2] Bouveault, *Bull. Soc. Chim.* (iii.), **17**, 999.

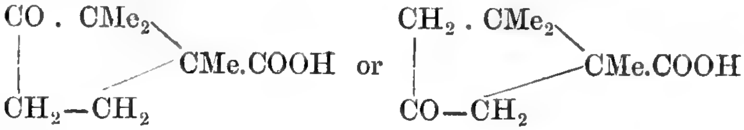
Moreover, dihydroisolauronic acid when warmed with dilute sodium hypobromite is converted into a tribasic acid, $C_9H_{14}O_6$, which loses carbon dioxide when heated, yielding *aa*-dimethyladipic acid.



Dihydroisolauronic Acid. Intermediate Product. *aa*-Dimethyladipic Acid.[1]

(ii.) *Electrolysis of* Allo-*Ethyl Hydrogen Camphorate.*—When this ester is electrolysed it yields a mixture of esters, chief amongst which is that of (a) *allo*-campholytic acid, a $\beta\gamma$-unsaturated acid, as it readily affords campholactone on treatment with acids : it is probably stereoisomeric with lauronolic acid,[2] and (b) of camphononic acid produced by the superposition of electrolysis and oxidation.

The constitution of lauronolic acid and *allo*-campholytic acid has not been determined, but one must assign to camphononic acid one of the following two formulæ



as it is readily obtained by the mere action of heat on the open chain tricarboxylic acid, homocamphoronic acid, and must therefore be a pentamethylene and not a tetramethylene derivative ; for since it affords camphoronic acid (F. 1. a. ii.) on oxidation it could only be one of these.[3]

It should be pointed out that the first of the two formulæ above given is almost certainly the correct one, as camphononic acid does not at once afford an oxime or hydrozones as do the majority of acids having the carbonyl group in attachment to two CH_2 groups. Moreover it cannot be made to combine with hydrogen cyanide, and it is therefore highly probable that the reactivity of the carbonyl group is affected by its attachment to a carbon atom on which no hydrogen is present.[4]

(b) *Action of Aluminium Chloride and of Sulphuric Acid on Camphoric Anhydride.*

When camphoric anhydride is brought into contact with aluminium chloride in chloroform solution it loses carbon monoxide and yields chiefly isolauronolic acid.[5] A third method of obtaining isolauronolic acid is supplied by the following series of changes. Camphoric acid when warmed with sulphuric acid yields sulphocamphylic acid by loss of the elements of formic acid and addition of the elements of sulphuric acid.

[1] Compare Bouveault, *Bull. Soc. Chim.* (iii.), **17**, 999, and **19**, 462; and Blanc, *Bull. Soc. Chim.* (iii.), **19**, 277, 350, 533, and 699; **21**, 830; and **23**, 107 and 273; and Perkin, *Trans. Chem. Soc.*, **73**, 796.

[2] Walker, *Trans. Chem. Soc.*, **69**, 748.

[3] Compare Bredt and Rosenberg, *Annalen*, 1896, **289**, 13 ; Wislicenus, *ibid.*, **275**, 309 ; and Perkin and Crossley, *Trans. Chem. Soc.*, **73**, 6.

[4] See Lapworth and Chapman, *Trans. Chem. Soc.*, **75**, 989, and **77**, 446, and Lapworth, *ibid.*, **75**, 1134.

[5] Blanc, *Bull. Soc. Chim.* [iii.], **15**, 1191.

This sulpho-compound when treated with superheated steam breaks up into isolauronolic and sulphuric acids.[1]

(c) *Action of Hypobromites on the Isomeric Camphoramic Acids.*

(i.) When α- camphoramic acid is warmed with sodium hypobromite it is converted into aminodihydrolauronolic acid in accordance with the equation

$$COOH.C_8H_{14}.CONH_2+Br_2+2KOH=COOH.C_8H_{14}.NH_2 \\ +2KBr+CO_2+H_2O.$$

This amino-acid on treatment with nitrous fumes yields a hydrocarbon C_8H_{14}, $\beta\gamma$-lauronolic acid, $C_8H_{13}.COOH$, isocampholactone, $C_9H_{14}O_2$, and an acid, melting at 180°, which has the formula $C_9H_{14}O_6$.

Hydroxydihydrolauronolic acid may be obtained from the ethyl ester of the amino acid by means of nitrous acid and subsequent saponification. On treatment with cold chromic acid mixture it loses carbon dioxide and is converted into a ketone; a behaviour which appears to indicate that the hydroxyl group is in the β-position with regard to the carboxyl group.[2]

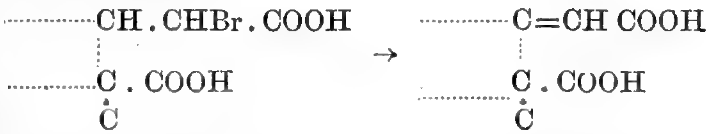
(ii.) When β-camphoramic acid is subjected to the action of hypobromite it suffers a change similar to that which the α-acid undergoes, and is converted into amino-dihydrocampholytic acid. This, on treatment with nitrous acid, yields a hydroxy-acid and subsequently campholytic and isolauronolic acids. The elimination of the *allo*-carbonyl group in this manner, therefore, leads to results similar to those already mentioned.[3]

3. Oxidation of Dehydrohomocamphoric Acid.

When homocamphoric acid is brominated it affords a mono-bromo-acid, as usual an α-derivative: the ethyl ester of this mono-bromohomocamphoric acid when heated with quinoline loses hydrogen bromide, and the product, after saponification, yields, amongst other things, dehydrohomocamphoric acid, naturally an $\alpha\beta$-unsaturated acid

$$C_8H_{14}\left\langle\begin{array}{l}CHBr\,.\,COOH\\COOH\end{array}\right. \rightarrow C_8H_{13}\left\langle\!\!\langle\begin{array}{l}CH\,.\,COOH\\COOH\end{array}\right. +HBr$$

or writing it in accordance with what we know regarding the constitution of homocamphoric acid (B. 2. b.)



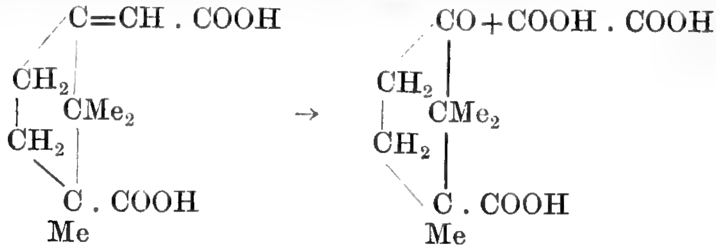
When the latter acid is oxidised with cold dilute permanganate it is

[1] Walther, *Ann. Chim. Ph.* [iii.], **9**, 177; Kachler and Spitzer, *Annalen*, **169**, 179, and Perkin, *Trans. Chem. Soc.* **73**, 796.

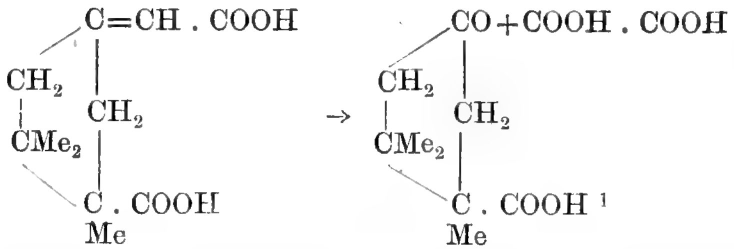
[2] Noyes, *Amer. Chem. Journ.*, **16**, 500; *Ber.*, **28**, 547, and **29**, 2326.

[3] Noyes, *Amer. Chem. Journ.*, **16**, 500; *Ber.*, **27**, 917, **28**, 547, and **29**, 2326.

converted into oxalic acid and camphononic acid (compare E. 2. a ii.), an action which apparently must be expressed as follows :



or



4. Formation and Properties of the Campholenic Derivatives.

The isomeric substances α- and β-campholenic acids are obtained in several ways, the most important of these being the dehydration of camphoroxine by various methods, when their nitriles are produced in large quantities :

$$C_{10}H_{16}:N.OH=C_9H_{15}\,.\,CN+H_2O.$$

Interesting, also, is the fact that α-campholenic acid is found amongst the products obtained by the action of sodium amalgam on β-dibromocamphor.

$$C_{10}H_{14}\,Br_2O+2H+H_2O=C_9H_{15}\,.\,COOH+2HBr.$$

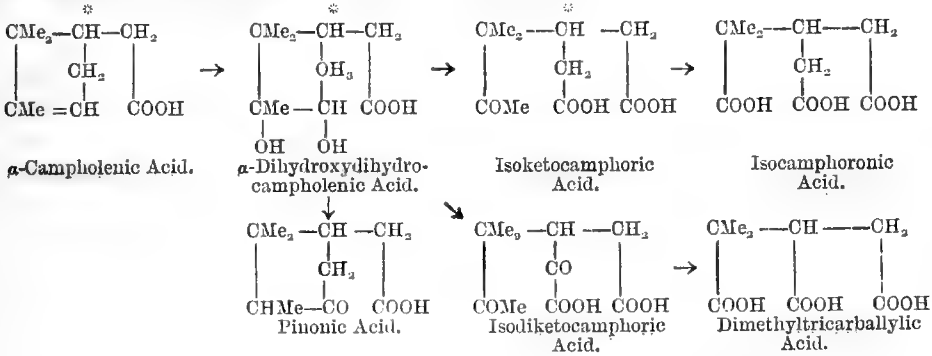
The campholenic acids are undoubtedly both unsaturated monobasic acids containing one closed carbon chain. The α-acid is optically active, whilst the β-acid and all its derivatives are quite inactive ; so that both the asymmetric carbon atoms of camphor have been involved in the change whereby this substance is produced. Both the α- and the β-acids have the double or ethylenic linking at the γ- or δ-position, as both are readily converted into lactones when treated with dilute acids.

α-Campholenic acid may be converted into β-campholenic acid by several processes, and invariably becomes inactive during the process. It would appear from this that β-campholenic acid is a secondary product of change.

Each acid, on oxidation with potassium permanganate, is converted into a dihydroxydihydrocampholenic acid by addition of the elements of hydrogen peroxide in the usual way. When these dihydroxy acids are distilled they are converted by loss of water into new substances, presumably ketonic acids, the α-acids affording pinonic acid, which is an oxidation product of pinene.

[1] Lapworth, *Trans. Chem. Soc.*, 77, 1056.

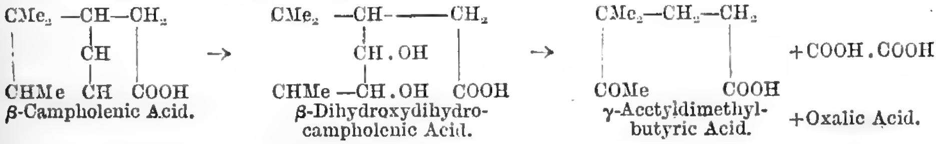
α-Dihydroxydihydrocampholenic acid is *dextrogyrate* and on oxidation with chromic acid yields *inactive* isoketocamphoric acid, and with nitric acid gives isodiketocamphoric acid. Both of these latter contain acetyl groups, and isoketocamphoric acid is converted into bromoform and isocamphoronic acid (E. 1. a. ii.) on treatment with cold hypobromite. These changes are expressed by Tiemann [1] as follows :—



This scheme expresses the foregoing facts in a highly satisfactory manner, including the cessation of inactivity with the passage from α-dihydroxydihydrocampholenic acid to isoketocamphoric acid, and appears, moreover, to be the only mode of doing so. The inadequacy of any formula for campholenic acid or pinonic acid which does not contain the group

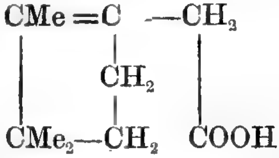
$$.\underset{\displaystyle C}{CMe}\,.\underset{\displaystyle C}{CMe_2}$$

is shown by the fact that one of the products obtained by oxidising pinonic acid is hydroxytrimethylsuccinic acid, $COOH.CMe(OH).CMe_2.COOH$. β-Dihydroxydihydrocampholenic acid (of course inactive, since β-campholenic acid has this property) on further oxidation with dilute permanganate yields oxalic and γ-acetyldimethylbutyric acid, which affords α-dimethylglutaric acid on treatment with alkaline hypobromite. Tiemann expresses these facts in the following way :—



Such a change as that assumed in the transformation of the dihydroxy-acid is obviously inadequate without further proof. Moreover the inactivity of β-campholenic acid receives no explanation whatever, as it is scarcely conceivable that the asymmetry of the carbon atom to which the activity of α-campholenic acid is due has been in any way destroyed.

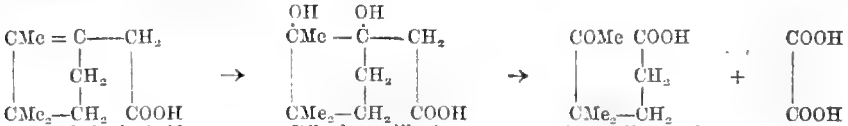
Proceeding backwards in a logical manner from the fact of the formation of γ-acetyldimethylbutyric acid and oxalic acid, we are led almost inevitably to the formula for β-campholenic acid which was first suggested by Bouveault,[2] namely—



[1] *Ber.*, **29**, 3006, and **30**, 409.

[2] *Bull. Soc. Chem.* [iii.], **19**, 565.

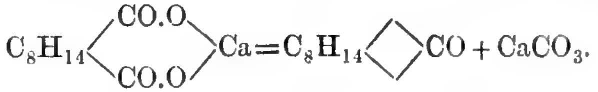
which contains no asymmetric carbon atom ; the oxidation of the acid is then readily understood :



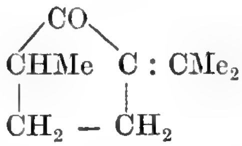
β-Campholenic Acid. β-Dihydroxydihydrocampholenic Acid. γ-Acetyldimethylbutyric Acid. Oxalic Acid.[1]

5. Formation and Constitution of Camphorphorone.

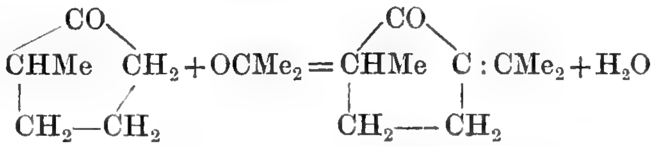
When the calcium salt of camphoric acid is subjected to the action of heat it is converted into calcium carbonate and camphorphorone, $C_9H_{14}O$:—



Camphorone has the structure



as it is converted into α-methylglutaric acid on oxidation, and may be synthetically prepared by the action of sodium ethoxide on a mixture of α-methylketopentamethylene and acetone. Since these condensations in saturated ketones occur only at a —CH_2.CO— group, the action must be expressed



as camphorphorone does not contain an acetyl group.[2]

F.—THE FORMULA OF CAMPHOR.

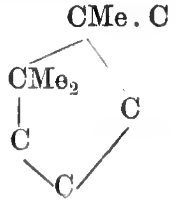
The earlier speculations regarding the constitutional formula of camphor require no special discussion at the present time, as they are of merely historical interest, and there is no doubt that the first great advance was made by Bredt in his paper on 'The Constitution of Camphoronic Acid,'[3] and the value of his deductions has been greatly enhanced since the achievement of the synthesis of this acid by Perkin and Thorpe,[4] which provided a complete proof of the formula suggested for it by Bredt.

Starting from the formula of camphoronic acid, as it is generally agreed we may do, and taking into account the fact that camphor readily yields cymene by the action of various agents, Bredt was led to advance the formula associated with his name. This formula has since been assailed by several chemists, notably Noyes, Tiemann, Bouveault, Blanc,

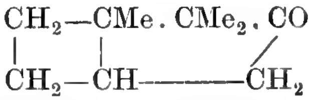
[1] See also Tiemann, *Ber.*, **28**, 1079, 2166, &c.
[2] Bouveault, *Bull. Soc. Chim.* [iii.], **23**, 160.
[3] *Ber.*, **26**, 3049.
[4] *Trans. Chem. Soc.*, **71**, 1169.

Walker, and Perkin, but the formula suggested by Tiemann must now be regarded as quite out of the question; whilst the formula specially advocated by Perkin, whilst greatly preferable, is now known to have no probability in its favour. It is significant that the chemists who at the present day strenuously advocate the acceptance of any formula other than Bredt's have made a special study of isolauronolic acid.

Latterly chemists have come to regard it as definitely established that camphor contains the grouping

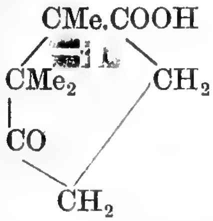


and it is easily demonstrated that besides three formula containing this complex, only one other structure for camphor can be devised which contains the grouping of carbon atoms of camphoronic acid, and also conforms to the established conditions referred to in B, C, and D. That formula is

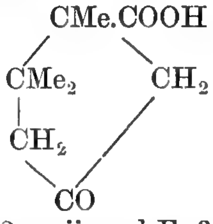


but nothing further can be said in favour of it.

Conclusive proof that the above trimethylpentamethylene nucleus is present in camphor is afforded by the fact that camphononic acid, which is obtainable from camphor in three entirely different ways, two of these involving no change in the hydrogenised nucleus, undoubtedly has the formula



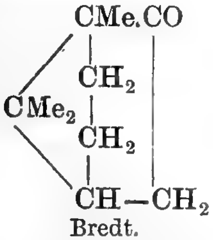
or



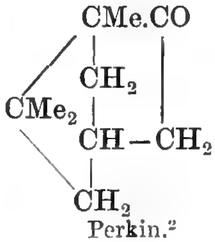
[1]

(Compare E. 2. a. ii. and E. 3.)

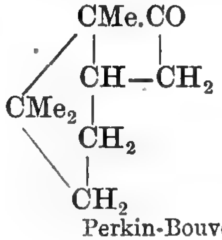
The only formulæ which contain this complex, and conform to the established conditions, are the Bredt, Perkin, and Perkin-Bouveault formulæ, namely



Bredt.



Perkin.[2]



Perkin-Bouveault..

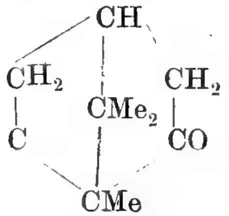
[1] *Trans. Chem. Soc.*, **71**, 1169.

[2] In Perkin's original paper, *Trans. Chem. Soc.*, **73**, 819, the position of the —CO— and —CH_2— group in the ketone ring is the inverse of the above.

of which the second, as has already been stated, has nothing further in its favour, and it does not appear possible to explain by its use the properties and constitution of many important products obtained by degrading the camphor molecule in the various ways detailed in E.

It is quite clear, therefore, that in the light of our present knowledge only two formulæ for camphor can be regarded as in the slightest degree probable, namely, the Bredt and the Perkin-Bouveault formulæ; and although it might at first sight appear an easy matter to decide between two formulæ so different in configuration, each still finds support in apparently incontrovertible evidence. A list of the facts to which each formula appears capable of ready application may be dealt with in turn, only those points being taken which appear to be of use in coming to a decision as to the relative value of the two formulæ.

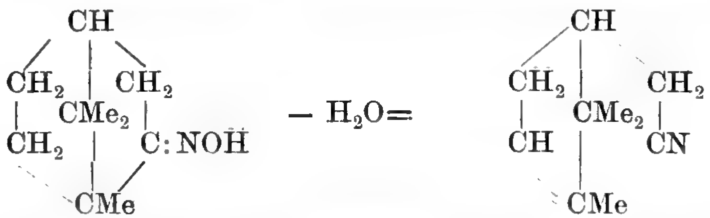
1. Bredt's Formula:



affords simple explanations of the following points:—

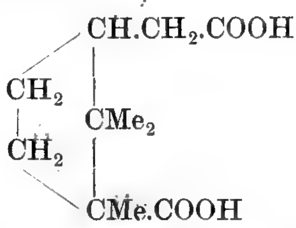
(a) *The Constitution of α-Campholenic Acid and its Oxidation Products.*

The formation of a nitrite having the highly probable constitution assigned to α-campholenonitrite by Tiemann is readily explained as follows (compare E. 4.)



(b) *The Non-formation of an Anhydride from Homocamphoric Acid.*

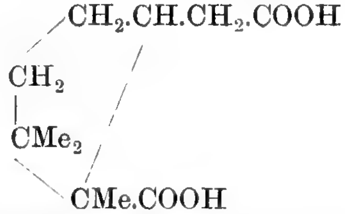
In accordance with Bredt's formula, homocamphoric acid must have the formula (compare B. 2. b. and E. 3.)



Homocamphoric acid has been shown to be incapable of yielding an anhydride,[1] a fact with which the above formula is in accordance, as it

[1] Bredt, *Ann.*, 289, 5.

represents a substituted adipic acid, derivatives of which are almost invariably incapable of affording anhydrides when treated by the ordinary processes. Using the Perkin-Bouveault formula, homocamphoric acid would have the structure



which is that of a glutaric acid, and should therefore be expected to yield an anhydride fairly readily, unless the structure is that of a *trans*-acid, an assumption which appears to be excluded by the fact that d-camphoric acid from which it is easily obtained is a *cis*-acid, the corresponding *trans*-acid being represented by *iso*-camphoric acid.

(c) *The Formation of Camphor in large Amount by distilling the Barium Salt of Homocamphoric Acid* (compare B. 2. c.).

As pointed out by Bredt and Rosenburg,[1] Wislicenus [2] and Perkin and Crossley,[3] the formation of considerable quantities of ketones by distillation of the barium or calcium salts of dibasic acids, in the simple manner here observed, is met with only amongst the derivatives of adipic, pimetic, and suberic acids, and never amongst those of glutaric acid, so that here again the Perkin-Bouveault formula appears inadmissible.

(d) *The extraordinary Readiness with which p-Cymene and its Derivatives are obtained from Camphor.*

This change, a knowledge of which assisted Bredt in devising his formula, is very readily understood by means of it :

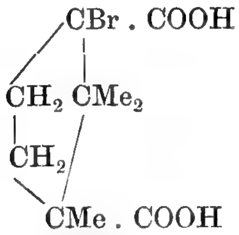
Camphor. $\rightarrow$ *p*-Cymene.

(e) *The ready Formation of the Lactonic Acid, Camphanic Acid from Bromocamphoric Acid or its Anhydride, and of its Ethyl Ester by heating Diethyl Bromocamphorate.*

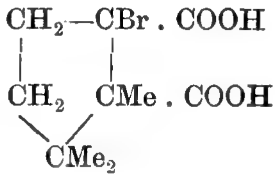
When *w*-bromocamphoric acid or its anhydride (obtained by the direct bromination of camphoric acid) is treated with water, alkalis, or sodium acetate dissolved in glacial acetic acid, it yields camphanic acid, a very stable lactonic acid. The great stability of the lactone ring of camphanic acid excludes the idea that it is of the nature of a β-lactone, so that it must be a γ-lactone. *w*-Bromocamphoric acid would therefore appear to be a γ-bromo-acid, and, in accordance with Volhardt's rule, it should also

[1] *Annalen*, **289**, 13.
[2] *Ibid.*, **275**, 309.
[3] *Trans. Chem. Soc.*, **73**, 6.

be an α-bromo-acid. These facts are readily explained by Bredt's, but not by the Perkin-Bouveault formula, as in accordance with our ordinary views the latter formula would make α-bromocamphoric acid a β- and not a γ-bromo-acid.



Bredt.

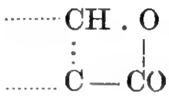


Perkin-Bouveault.

That the position of the bromine atom in the nucleus represents the position of attachment of the lactonic oxygen atom is shown by (1) the fact that diethylbromocamphorate when heated yields ethyl bromide and ethyl camphanate

(2) that camphanic acid on treatment with phosphorus pentachloride (or pentabromide) regenerates ordinary chloro- (or bromo-)camphoric chloride (or bromide); a fact of which the author has convinced himself.

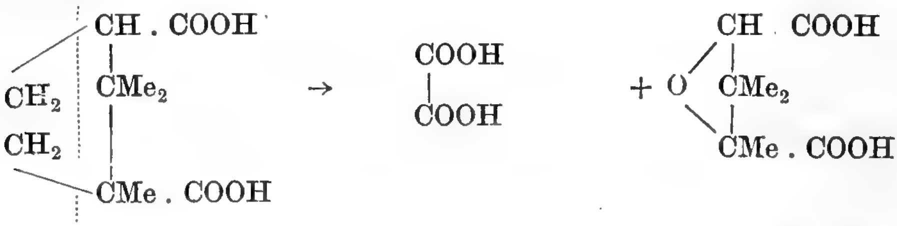
That camphanic acid does not contain the grouping



receives support in the fact that it is obtained by oxidising camphoric acid with chromic acid, and in accordance with the researches of Fittig such an oxidation occurs only at the tertiary carbon atoms.

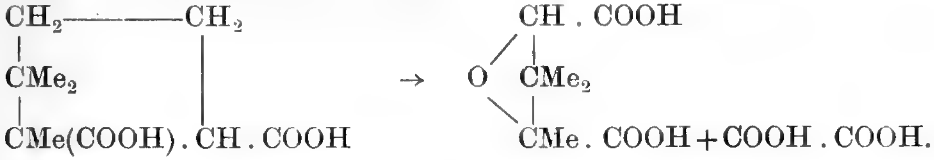
(f) *The Formation of Balbiano's Acid and Oxalic Acid in approximately equivalent Amount by the Oxidation of Camphoric Acid* (compare E. 1. b.).

The formation of an acid having the constitution given by Balbiano for the product $C_8H_{14}O_5$ is readily interpreted by the use of Bredt's formula as follows:—



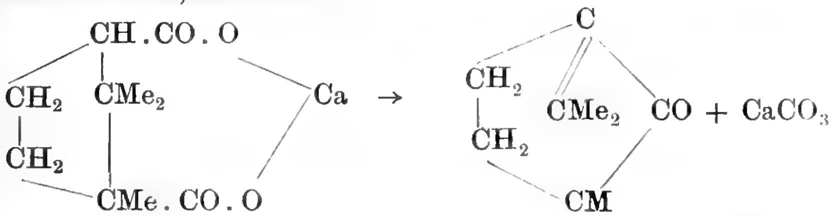
Using the Perkin-Bouveault formula, the course of the change becomes very difficult to understand, and must necessitate the assumption that a

—CH_2— group in a hydrocarbon ring may be converted into —CH(OH)— or —CO— or others equally improbable :

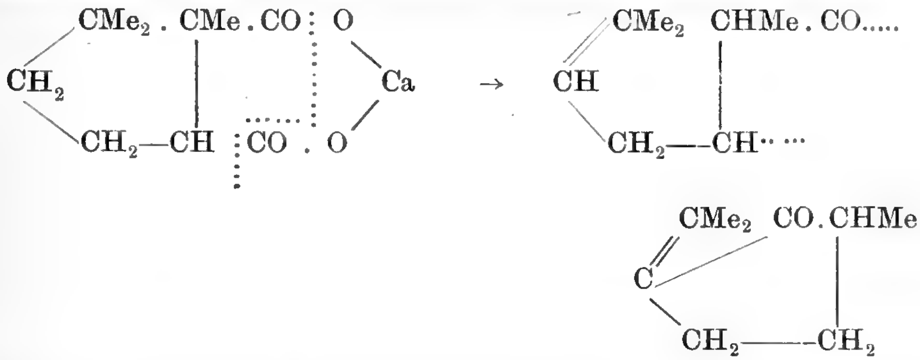


(g) *The Formation of Camphorphorone* (compare E. 5.).

The formation of a ketone having the constitution of camphorphorone from calcium camphorate receives instant explanation by means of Bredt's formula, as follows :



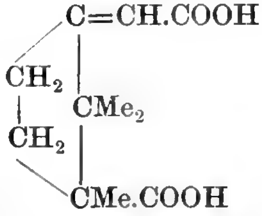
whilst if the Perkin-Bouveault formula is used the change must be represented as the result of the following complicated series of reactions : [1]



a necessity which leaves the probabilities greatly in favour of the first depicted.

(h) *The Formation of Camphononic Acid and Oxalic Acid from Dihydrohomo-Camphoric Acid* (compare E. 3.).

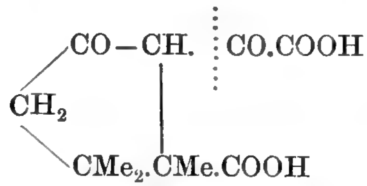
As has already been mentioned (*loc. cit.*) this change appears capable of only two simple explanations, one of those being the assumption that dihydrohomocamphoric acid has the formula which would be attributed to it were Bredt's formula the correct one, namely



[1] Compare Bouveault, *Bull. Soc. Chim.* [iii.], **19**, 462.

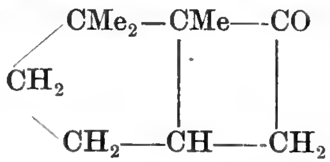
and not only is this the case, but the derived formula of camphononic acid is in complete accordance with the disinclination of the carbonyl group to form additive complexes (compare E. 2. a. ii.).

The Perkin-Bouveault formula is, in this instance also, inapplicable, unless, as usual, a special assumption is made to meet the case. Thus, no doubt, it might be held that an intermediate compound having the formula



is produced which breaks up into oxalic acid and camphononic acid by hydrolysis. Such an assumption, however, has nothing to recommend it.

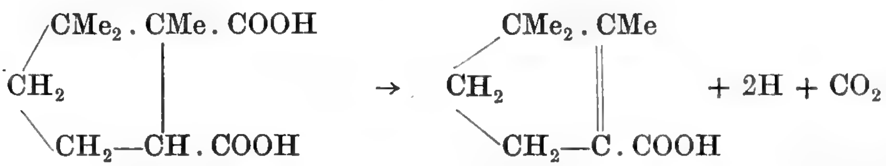
2. The Perkin-Bouveault Formula.



This formula offers simple explanations of the following points, for which the Bredt formula appears inadequate.

(a) *The Formation of Isolauronolic Acid from Camphoric Acid in several Ways.*

The formation of this acid by elimination of the *allo*-carboxyl group from camphoric acid is readily explained by the use of this formula :



The change represents the formation of acids having the formula proved by Blanc to be correct for isolauronolic acid, and of course affects both asymmetric carbon atoms, thus explaining the complete disappearance of optical activity during their formation.

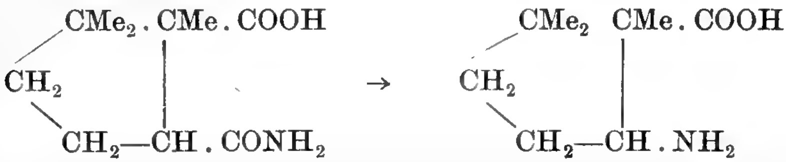
(b) *The formation and properties of β-campholenic acid.*

In explaining the production of a campholenonitrile from camphoroxime, as represented by the Perkin-Bouveault formula, we are led in a most simple manner to the formula, which, as was pointed out by Bouveault, is the most suitable one for β-campholenonitrile which can be devised :

whilst it is clear that the use of Bredt's formula would require the assumption that isomeric change of a somewhat obscure character had taken place. If this formula be the correct one, β-campholenic acid, as might be surmised from a consideration of its inactivity and its oxidation products, is in reality homoisolauronolic acid.

(c) *The Formation and Properties of Hydroxydihydrolauronolic Acid.*

By the use of the Perkin-Bouveault formula the action of hypobromite on α-camphoramic acid would be represented



and the formula so deduced for the amino-acid represents a β-amino acid, which should naturally afford a β-hydroxy acid on treatment with nitrous acid. Since a β-hydroxy acid would yield a β-ketonic acid on oxidation, the elimination of carbon dioxide and production of a ketone are easy to understand (compare E. 2. c. i.).

A consideration of the whole of the preceding facts leads to the conclusion that it is impossible to reconcile the results obtained in the various departments of camphor chemistry without having recourse to the assumption that, at certain points, intramolecular change takes place, involving new arrangements of the carbon atoms. Thus, to take only one example, the structure of the α- and β-campholenic acids cannot be represented by two formulæ which differ only in the position of the double binding as Tiemann suggested, for one acid clearly contains the grouping

$$:CMe\,.\,CMe_2 \quad CH\!\!<\!\!\begin{matrix}C\,.\,C\\C\,.\,C\end{matrix}$$

and the other the complex

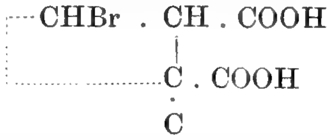
$$\vdots C\,.\,CMe_2\,.\,CH_2\,.\,C\,.\,C.$$

The formation of isocamphoronic acid on the one hand and of isolauronolic acid on the other is also incapable of explanation on any other grounds than that of intramolecular change; and it would appear advisable, therefore, to consider the whole of the evidence from a broad standpoint, and, having decided which is the more probable view, to endeavour to ascertain the points at which difficulties first arise, and only then to seek for explanations. It is obvious that it would be altogether ill-advised to adopt the usual course and to take any one derivative, however well established its structure may be, and however simple its apparent mode of derivation, and to use this as the basis on which to form our conclusions, employing a forced explanation for each inconvenient fact in turn.

Looking at the question, first, from a general point of view, without regard to ultimate structure, it must be obvious that the probabilities are greatly in favour of the view that the ketone ring in camphor is a pentamethylene nucleus, as witness the readiness with which the substance is obtained from homocamphoric acid. Moreover the properties of homocamphoric acid itself approach more nearly those of an adipic than glutaric acid, since under no circumstances does it appear to yield an anhydride.

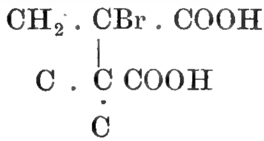
The general properties of camphoric acid are those of a glutaric acid, as its bromo-derivative at once yields a stable lactone; a behaviour altogether inconsistent with the view that it is an α-brominated succinic acid.

The supporters of the succinic acid formula for camphoric acid have raised the contention that bromocamphoric acid is a β-brominated acid containing the complex

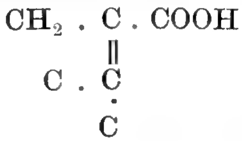


and in support of this advance the fact that its anhydride on treatment with water or sodium carbonate loses carbon dioxide and hydrogen bromide, yielding a small quantity of lauronolic acid, a behaviour certainly in accordance with the view that it is a β-bromo-acid. The necessity for such an assumption, however, is in itself clearly an argument against the succinic formula, since the bromination of a saturated acid in the β-position is unknown. Moreover on this assumption bromocamphoric anhydride itself still contains an α-hydrogen atom, and should be capable of further bromination, a surmise altogether at variance with the facts. It is much more probable that the formation of lauronolic acid is due to an idiosyncrasy of the compounds involved, and little or nothing is known of the behaviour of cycloid α-bromo-acids in this respect.

It obviously cannot be urged that the formation of lauronolic acid is evidence in favour of the presence of the complex



as such an acid would afford an isomer of lauronolic acid, possibly campholytic or isolauronolic, and containing the complex



and, in fact, that it does not do so is in itself evidence against the succinic formula for camphoric acid.

It may therefore be stated that the general properties of camphor and camphoric acid are of a kind which should be expected were Bredt's formula the correct one.

Comparing now the weight of evidence in favour of the two formulæ as elicited by examination of the exact structure of the degradation products of camphor, Bredt's formula is seen to be favoured in a high degree, and only the structure of isolauronolic acid and of β-campholenic acid (probably, as has been pointed out, homoisolauronolic acid) appears to militate strongly against its acceptance. It is especially significant, moreover, that the β-campholenic derivatives are produced, probably in all cases, as secondary products from the α-derivatives, and the behaviour

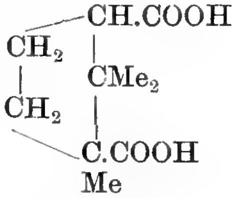
of the latter is in strict accordance with the requirements of Bredt's formula.

It is certainly difficult to understand the behaviour of hydroxydihydrolauronolic acid, but until more is known of this acid it is possible to attach undue significance to the point.

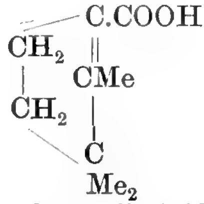
It is impossible to overlook the fact that the Bredt formula affords an excellent explanation of the behaviour of a very large number of camphor derivatives, and is, in fact, the only formula which will do so, and that the same words apply to the Perkin-Bouveault formula when the remainder, namely, isolauronolic acid and β-campholenic acid, are referred to.

Since the constitutions of the two different series of compounds appear to have been established with such a high degree of probability, one is led to the belief that there may, after all, be some close connection between the two series which has escaped observation owing to the occurrence of unsuspected isomeric change—a phenomenon which it is generally admitted must be the cause of the present divergence of opinion on the matter.

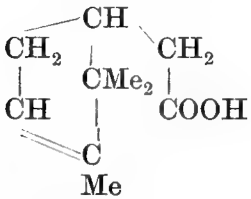
It does not require much consideration to observe that if this explanation be correct the isomeric change must occur during the formation of isolauronolic acid, and in the transformation of the α- to the β-campholenic derivatives, so that a comparison of the probable formulæ of these substances before and after the change should allow us to gather if there is any simple connection between them.



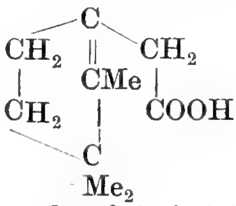
Camphoric Acid.



Isolauronolic Acid.

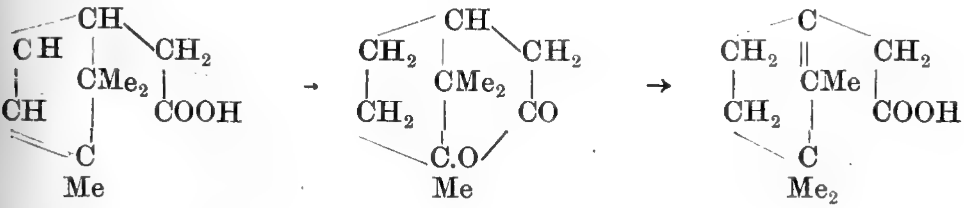


α-Campholenic Acid.



β-Campholenic Acid.

It is fairly clear that the apparent change consists in the migration of a methyl group to an adjacent carbon atom in both cases. The alteration of the position of the double binding in the campholenic derivatives is of little consequence, as the change is probably preceded by the formation of a lactone in some cases, of an imide in others, and these derivatives contain no double binding. Possibly the change in the former case may be represented



The change is not unlike that involved in the transformation of pinacone into pinacoline :

$$\begin{array}{l}\mathrm{CMe_2.OH}\\ |\\ \mathrm{CMe_2}\\ |\\ \mathrm{OH}\end{array} \quad \rightarrow \quad \begin{array}{l}\mathrm{CMe_3}\\ |\\ \mathrm{CMe}+\mathrm{H_2O}\\ \|\\ \mathrm{O}\end{array}$$

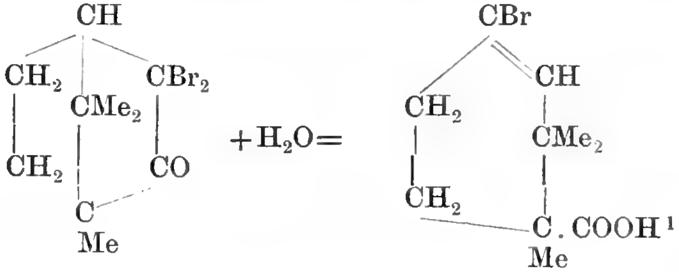
or of pinacolyl alcohol into tetramethylethylene :

$$\begin{array}{l}\mathrm{CMe_3}\\ |\\ \mathrm{CHMe.OH}\end{array} \quad \rightarrow \quad \begin{array}{l}\mathrm{CMe_2}\\ \|\\ \mathrm{CMe_2}\end{array} + \mathrm{H_2O}$$

changes apparently characteristic of complexes which contain several adjacent methyl groups. It is well known, moreover, that in the formation of benzenoid derivatives from hexamethylene compounds the methyl groups usually appear to move to adjacent carbon atoms ; as, for example, in the change of isolauronic acid into paraxylic acid

as well as in numerous similar instances investigated by Baeyer.

It may be urged that the conditions under which isolauronolic acid is produced from camphor are not such as would be expected to produce deep-seated isomeric change, but such a contention is altogether insufficient to seriously militate against the great probability that it does actually occur in this instance. It is easy to cite evidence that isomeric changes of very unexpected character do occur under conditions which would at first sight appear to be insufficient to produce them, such as, for example, the change of α-dibromocamphor into bromocamphorenic acid when warmed with an alcoholic solution of silver nitrate on the water bath, which certainly involves the absorption of a carbon atom into a ring somewhat in this manner :



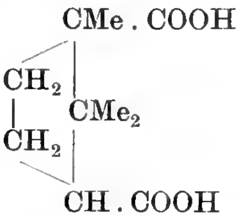
and the change of pinacone into pinacoline does not involve any violent action such as is usually associated with the production of benzene derivatives from cyclomethylene compounds.

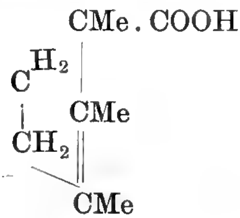
[1] Lapworth, *Trans. Chem. Soc.*, **75**, 1138.

Finally, whilst it appears unlikely that any simpler explanation than that here suggested can be offered, the question clearly awaits further investigation; but it seems unlikely that the correct solution will be obtained until the attention of investigators is directed to the examination of the points at which isomeric change probably occurs, since the discovery of isolated facts in favour of either formula can only add to the number of those already known, and can scarcely be regarded as conclusive whilst strong evidence in favour of the other formula can be brought forward.

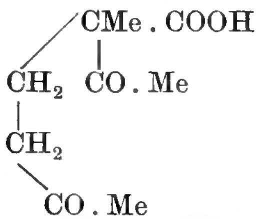
Addendum (*November* 3, 1900).

The curious properties of lauronolic acid (2. a. ii.) may possibly be accounted for by the occurrence of a change of structure similar to that above suggested in the cases of β-campholenic acid and isolauronolic acid, and by applying a similar rule, the change might be represented

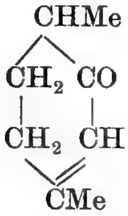

Camphoric Acid.


Lauronolic Acid.

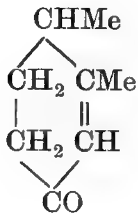
and the formula thus arrived at is in complete accordance with all that is at present known of the properties of the acid, and on oxidation the acid would be converted into a compound



which is, at the same time, a β-ketonic acid and a 1 : 5-diketone, and would therefore lose carbon dioxide readily, and suffer condensation in alkaline solution, yielding a $\beta\gamma$-unsaturated ketone



or



with the properties of the laurenone obtained by Tiemann and H. Tigges[1] on oxidising lauronolic acid with potassium permanganate.

[1] *Ber.*, 33, 2950.

Canadian Pleistocene Flora and Fauna.—Report of the Committee, consisting of Sir J. W. DAWSON (*Chairman*), Professor D. P. PENHALLOW, Dr. H. AMI, Mr. G. W. LAMPLUGH, and Professor A. P. COLEMAN (*Secretary*), *reappointed to continue the investigation of the Canadian Pleistocene Flora and Fauna.*

DURING the past year the Committee has suffered a severe loss through the death of its distinguished chairman, Sir J. W. Dawson, but the work has been continued by three of its members. Dr. Ami has taken charge of the Ottawa valley deposits, Professor Penhallow has examined the fossil flora from both Ottawa and Toronto, and the Secretary has continued his investigations near Toronto. The following report on the Pleistocene near Toronto has been prepared by the Secretary, and that on the Flora of the Don Valley by Professor Penhallow.

I. *On the Pleistocene near Toronto. By* Professor A. P. COLEMAN.

Since the preparation of the last report two new localities near Toronto have proved of interest, one near a bend of the Don a little east of the well reported on last year, the other a series of sand deposits in the western part of the city. The outcrop at the bend of the Don just north-west of Toronto was discovered years ago by Dr. G. J. Hinde, who had described so excellently the section at Scarborough Heights, and who has been good enough to hand over his material to the Secretary. Until last year, however, it was not certainly proved to be interglacial. The section at the bend of the Don is of special interest, since it occupies an interglacial valley about 700 feet wide, having steep walls of Hudson River (Cambro-silurian) shale, rising 8 or 10 feet on the eastern side and 16 feet on the western. The section is as follows :—

4. Coarse gravel with boulders and no shells, 4 to 8 feet . .	37 to 40
3. Brown clay with sandy layers containing unios, &c., 4 or 5 feet	33 or 34
2. Blue clay with sandy layers containing shells and wood, 6 feet	29
1. Coarse shingle with clay and peaty layers, 4 feet . . .	23
River Don, above level of Lake Ontario	19

The lowest layer goes below the level of the Don, so that the bottom of the section is not exposed. The third layer corresponds exactly in materials and fossils with the unio beds referred to in last year's report, which are in place 100 yards to the west, and there overlie a thin sheet of boulder clay resting on a cliff of shale 16 feet in height. Beds 1 and 2 contain trees of a warm climate, as determined by Professor Penhallow, and twelve species of freshwater shells, according to determinations kindly made by Dr. Dall of the Smithsonian Institution, Washington, two of the shells, *Unio* (*Quadrula*) *pyramidata* and *Anodonta grandis*, being new to the Toronto formation.

The most important feature of this section is the evidence afforded that

a period of erosion, during which the floor of Hudson River shale was cut down more than 16 feet, preceded the deposit of the lowest warm climate beds. This, with the downward extension of the interglacial beds, as described in previous reports, for at least 15 feet, lengthens the time necessary for the interglacial episode considerably.

The new deposits in the western part of the city are exposed partly in cuttings for sewers, but chiefly in two large sandpits, now worked energetically because of the increase of building operations in Toronto. These exposures lie from three to four miles west of the Don and are either interglacial or preglacial, since more or less boulder clay overlies them, though wave-action on the old Iroquois shore, 160 feet above the present Lake Ontario, has removed part of the overlying till.

Sections at the sandpits near Christie and Shaw Streets show 30 to 40 feet of sand and gravel tumultuously cross-bedded, as if formed in a rapidly flowing river or near the shore of a large lake. The upper part of the stratified sand is often contorted and broken into irregular masses immediately under the till. The more gravelly layers contain a few shells, chiefly *Campeloma decisa*, *Valvata sincera*, species of *Pleurocera* and *Sphaerium*, and occasionally fragments of unios. A few mammalian remains have occurred also, fragments of a tusk of mammoth or mastodon, and an atlas vertebra of an animal not smaller than an ox, having been found within the past year. The latter bone could not be determined by comparison with the skeletons at hand in the Biological Museum of Toronto University, and so was sent by Mr. Archibald Pride of the Biological Museum, to whom it had been referred, to his brother in Dublin. There it was considered to belong probably to *Bison americanus*. Toronto is the most easterly locality in Canada where remains of this inhabitant of the prairies have been found.

As these stratified sands differ greatly from any of the interglacial beds of the Don or Scarborough, though underlying apparently the same sheet of till, it seemed possible that they were preglacial. To settle this point it was decided to sink a well to bed rock from the bottom of the Christie Street sandpit, using the grant of 10*l.* to the Committee for this purpose. As the sand below the bottom of the pits is heavily charged with water, it was necessary to drill the well and sink a pipe as the work progressed. After thirty-eight feet of rather uniform sand had been penetrated, a layer of cemented gravel or conglomerate put an end to the work with the appliances employed.

Another well was sunk half a mile to the south, near a stream which had cut through forty feet of till. Here the drill reached the underlying Hudson River shale, giving a complete section of the drift, as follows:

	ft.	in.	ft.	in.
Till, blue clay with a few scratched stones . .	40		99	
Fine and coarse grey sand	14		59	
Clay without stones	9	3	45	
Gravel (loosely cemented)	2	6	35	9
Clay without stones	2	9	33	3
Sand and gravel	13	6	30	6
Hudson River Shale			17	
Level of Lake Ontario			0	

As no boulder clay was found beneath the sand, the question remained undecided whether the beds are interglacial or preglacial; but the opening of a sewer on Dupont Street, half a mile north-east of the sandpits, has

since provided evidence favouring the interglacial age of the sands. At the sewer stratified sand, evidently a continuation of the deposits just mentioned, contains clayey sheets with thin bands of peaty material containing remains of beetles, mosses, seeds, plates of mica, &c., precisely like the peat from the cold climate series of Scarborough and the Don valley. Since these peaty layers are probably equivalent in age to the peaty clays east of the city, we may suppose that the sandy deposits of the western part of Toronto are also interglacial, in the upper part evidently belonging to the cold climate series, but perhaps representing the warm climate deposits at lower levels. It is clear that the conditions in Western Toronto must have been different from those to the east, since here a great thickness of stratified sand replaces stratified clay. This may be explained by supposing that an interglacial Humber river brought from the west sand and gravel into the great lake then occupying the Ontario Valley to mingle with the clayey delta materials of the interglacial Laurentian river flowing from Georgian Bay to Scarborough.

Just beneath a thin sheet of till in the Dupont Street sewer the upper end of the ulna of a mammoth or mastodon was found, the bone having been polished and scratched by glacial action, suggesting that it lay on the surface when the ice advanced for the last time. Some pieces of wood occurred near by, but lower down in the section.

We may now sum up the results obtained by the Committee and former investigators of the Toronto formation, so as to show the series of events recorded, the thickness of the deposits, and the fossils obtained from them.

In most places the Toronto formation is found to overlie a bed of characteristic boulder clay containing rocks brought from long distances to the north or north-east, and covering the eroded surface of the Cambro-silurian rocks of the region. This boulder clay probably belongs to the Iowan till sheet of the United States. After the retreat of the ice there was an interval of erosion shown near Shaw Street, and in the interglacial river valley at the bend of the Don ; followed by the deposit of clay, sand, and gravel containing trees and unios of a warmer climate than the present, the greatest thickness amounting to thirty-three feet in the Don valley, and to thirty-five feet below Lake Ontario at Scarborough.

These beds have nowhere been found at a higher level than fifty feet above Lake Ontario, and the upper sands and gravels were probably laid down in shallow water, since they are browned and sometimes cemented with oxide of iron.

Conformably upon the warm climate beds are a series of beds containing trees and other fossils, especially beetles, suggesting a cooler climate than the present ; not Arctic, however, but cold temperate. These are best shown at Scarborough Heights, where stratified peaty clays starting a few feet below the level of Lake Ontario have a thickness of ninety-five feet, followed by fifty-five feet of stratified sand. It is probable that part at least of the seventy feet of sand found in the western part of Toronto is of the same age. The interglacial lake at this stage must have stood at least 150 feet higher than Lake Ontario.

A long period of erosion followed the draining of this lake, during which river valleys a mile or more in width were cut through the delta deposits at Scarborough to the depth of more than 150 feet comparable to those cut by the Don and Humber since the Glacial period.

Finally a fresh advance of the ice, probably belonging to the Wisconsin

stage of American geologists, covered the Toronto formation with a complex series of layers of boulder clay and stratified sand and clay reaching a thickness of 200 feet at Scarborough Heights.

Accounts of the fossils of the Toronto formation have been given in previous reports of this Committee and in various articles in geological journals, but in this final report it is thought wise to give a more complete list of the species collected, including a large number that have not yet been published. As the trees will be taken up in Professor Penhallow's report, the present list is confined to the interglacial fauna. The forms occurring in the lower, warm climate beds will be given first, and afterwards those of the cool climate.

Fauna of Warm Climate Beds, Don Valley.

Vertebrata: possibly mammoth or mastodon and bison, and an undetermined fish.
Arthropoda: several undetermined beetles and cyprids.
Mollusca:

Unio undulatus	still living in Lake Ontario.
,, rectus	
,, luteolus	
,, gibbosus	
,, phaseolus	still living in Lake Erie, but not reported from Lake Ontario.
,, pustulosus	
,, trigonus	
,, occidens	not known in the St. Lawrence system of waters, but living farther south.
,, solidus	
,, clavus	
,, pyramidatus	

Anodonta grandis, not reported from Canada.

Sphaerium rhomboideum
,, striatinum
,, sulcatum
,, solidulum
,, simile (?)
Pisidium Adamsi
,, compressum
,, novaboracense (?)
Pleurocera subulare
,, elevatum
,, Lewisi (?)
Goniobasis depygis
,, Haldemani
Limnaea decidiosa
,, elodes
Planorbis parvus
,, bicarinatus
Amnicola limosa
,, porata
,, sagana
Physa heterostropha
,, ancillaria
Succinea avara
Bythinella obtusa
Somatogyrus isogonus
Valvata sincera
,, tricarinata
Campeloma decisa
Bifidaria armata (land snail)

In all there are thirty-eight undoubted species of molluscs, and three more probably, included in the fauna. Of these eight or ten have not been reported from Lake Ontario, but occur farther south.

Fauna of Cool Climate, chiefly from Scarborough.

Vertebrata : Caribou, and perhaps mammoth or mastodon and bison.
Arthropoda (almost wholly beetles) :

Carabidae (9 gen., 34 sp.).

Elaphrus irregularis
Loricera glacialis
" lutosa
" exita
Nebria abstracta
Bembidium glaciatum
" Haywardi
" vestigium
" vanum
" praeteritum
" expletum
" damnosum
Patrobus gelatus
" decessus
" frigidus
Pterostichus abrogatus
" destitutus
" fractus
" destructus
" gelidus
" depletus
Badister antecursor
Platynus casus
" Hindei
" Halli
" dissipatus
" desuetus
" Harttii
" delapidatus
" exterminatus
" interglacialis
" interitus
" longaevus
Harpalus conditus

Dytiscidae (3 gen., 8 sp.).

Coelambus derelictus
" cribrarius
" infernalis
" disjectus
Hydroporus inanimatus
" inundatus
" sectus
Agabus perditus

Gyrinidae (1 sp.).

Gyrinus confinis LeC.

Hydrophilidae (1 sp.).

Cymbiodyta exstincta

Staphylinidae (11 gen., 19 sp.).

Gymnusa absens
Quedius deperditus
Philonthus claudus
Cryptobium detectum
" cinctum
Lathrobium interglaciale
" antiquatum
" debilitatum
" exesum
" inhibitum
" frustum
Oxyporus stiriacus
Bledius glaciatus
Geodromicus stiricidii
Acidota crenata, Fabr. (*var.* nigra)
Arpedium stillicidii
Olophrum celatum
" arcanum
" dejectum

Chrysomelidae (1 gen., 2 sp.).

Donacia stiria
" pompatica

Curculionidae (4 gen., 6 sp.).

Erycus consumptus
Anthonomus eversus
" fossilis
" lapsus
Orchestes avus
Centrinus disjunctus

Scolytidae (1 sp.).

Phloeosinus squalidens

Mollusca :

Sphaerium rhomboideum
" fabale
Limnaea sp.
Planorbis sp.
Valvata tricarinata

If the sand deposits of Western Toronto are to be included with the cool climate beds, there must be added :

Campeloma decisa	Amnicola limosa
Pleurocera, two species	Valvata sincera
Goniobasis, one species	Unio, one species

These fossils may, however, belong to the lower warm climate series. The molluscs do not give decisive information as to the climate ; but the trees, and to a considerable extent the insects, point to a climate somewhat cooler than at present.

Dr. Samuel H. Scudder has determined these beetles, seventy-two in number, all of them in his opinion extinct except two. Twenty-five of them were obtained from material sent by Dr. Hinde, the rest from specimens collected at Scarborough and Toronto by A. P. Coleman. A complete account of the new species, with figures, will be published shortly by the Canadian Geological Survey. The new species confirm Dr. Scudder in the opinion expressed when the first set of specimens was described, 'that on the whole the fauna has a boreal aspect, though by no means so decidedly boreal as one would anticipate under the circumstances.' The Committee warmly appreciates the kindness and patience of Dr. Scudder in working up this fragmentary and difficult material.

In all at least seventy-eight species of animals are known from the cool climate beds, seventy of them extinct, and the total number may reach eighty-seven ; while in the lower warm climate beds at least fifty species are known to exist. Only four of the seventy-eight species recognised in the upper beds occur also in the lower beds ; so that 124 species of animals, chiefly insects and molluscs, but including also the caribou, bison, and mammoth or mastodon, have been found in the Toronto interglacial formation. If we include the flora, with its numerous forest trees, it will be seen that there are ample materials for reconstructing the life of the time and for determining the climate. That the Toronto formation is interglacial has been proved beyond doubt, and that it represents an interglacial period lasting thousands of years is scarcely doubtful. Two points are of special importance in this connection. In the first place, there was a considerable interval of erosion after the earlier withdrawal of the ice before the warm climate beds began to be deposited, and there was a long time of active erosion after the cool climate beds had been formed before the ice advanced for the second time. These times of erosion, with the long intervening time when the valley of Lake Ontario was filled with fresh water to a depth of 50 to 150 feet greater than at present, demand not only a great lapse of time but also important warpings and changes of level in the St. Lawrence valley. In the next place it is striking that none of the scores of species of plants and animals found is characteristic of an Arctic or even sub-Arctic climate. All of them might live in Ontario to-day except a few which require a warmer climate, *i.e.* they all belong to climates ranging from warm temperate to cold temperate, meaning by the latter the climate of the north shore of Lake Superior or of the lower St. Lawrence. The deposits seem to have been formed, not during the earlier retreat of the ice, nor during its second advance, but during a temperate era, when in all probability eastern Canada was as devoid of permanent icefields as it is to-day. Our investigations go far to prove that between the two

advances of the ice there was a long temperate interval during which even the heart of Labrador, 700 miles to the north-east, must have been free from glaciers.

II. *The Pleistocene Flora of the Don Valley.* *By* Prof. D. P. Penhallow.

Special studies relative to the pleistocene flora of Canada have now been carried on since 1889, the first report on the subject having been made by Dawson and Penhallow in 1890.[1] Other contributions have been made from time to time, but upon the occasion of the meeting of the British Association at Toronto in 1897 a special impetus was given to this work by the appointment of a Committee, to whom a grant was made for the purposes of investigation, particularly in the neighbourhood of Toronto. Under these favourable conditions much material has been brought together, chiefly from the immediate vicinity of Toronto, and its determination has thrown much important light upon the climatic conditions of the various geological phases through which that region evidently passed in interglacial times. During the past decade or more, other important material has been gathered from various localities—often most widely separated—throughout the Dominion. As the work of the Committee is now practically completed, it is considered wise, in this final report, to bring together all the information from these various sources and endeavour to ascertain its bearing upon questions of current interest and importance.

Plants from eighteen special localities have been studied, ranging from Manitoba to Cape Breton, and particular attention has been directed to those from at least twelve of these locations, chiefly from the vicinity of Toronto.

Eighty-three species in all have been studied, the largest number from any one locality (Taylor's Brickyard) being twenty-seven. In several instances only one or two species have been obtained from a locality, in which cases they afford no definite conclusions respecting the climatic conditions of the locality ; but in other cases the character of the vegetation is such as to leave no room for doubt as to the climatic conditions involved. In the Valley of the Don, numerous collections from the same localities have resulted in a constant diminution in the number of discoveries, until latterly the total absence of anything new has brought the conviction that the flora of the region has been exhausted, and an inspection of the accompanying table will at once serve to disclose the extent of the flora in each locality examined. The explorations of the past year have added nothing new to our knowledge of the flora of these localities, since the various plants found have proved to be only such as had been previously determined. There is therefore little to be added to the observations made in previous years, but attention may be directed to a few considerations of interest which appear upon comparison of the various localities studied.

Of the eighteen localities under observation, five are so distant from one another and from all others as to bear no obvious relation to each other, or else the plant-remains are so few as to render them of little value except from the general standpoint of geographical range. These localities are Cape Breton, Rolling River (Manitoba), Solsgirth and Leda

[1] *Bull. Geol. Soc. Amer.* I. (1890), pp. 311–334.

River (Manitoba), and Moose and Missinaibi Rivers. The remaining thirteen localities are so situated as to bear a more or less definite relation to one another, and all lie within the limits of the Pleistocene Sea which extended up the valley of the St. Lawrence, and occupied the area of the present Great Lakes. It should be kept in mind in this connection, however, that saltwater forms are to be met with only as far west as Green's Creek, near Ottawa, while freshwater types prevail in all the more western localities, which thus correspond in a general way with the deposits of Ohio, Indiana, Illinois, Minnesota, Manitoba, and other western regions.

Distribution of Pleistocene Plants.

—	Erie Clays	Cape Breton	Rolling River, Manitoba	Solsgirth, Manitoba	Leda River, Manitoba	Moose and Missinaibi Rivers	Don Valley							Scarborough	Green's Creek	Besserer's Wharf	Montreal
							Bottom of Logan's Clay	Don River	Gaol Farm	Taylor's	Price's	Simpson's	Bend of Don				
Abies balsamea														*			
Acer pleistocenicum								*		*							
„ saccharinum															*		
„ spicatum								*		*							
Algae sp.															*		*
Alnus sp.															*		
Asimina triloba									*								
Betula lutea																*	
Brasenia peltata															*		
Bromus ciliatus															*		
Carex aquatilis														*			
„ magellanica															*		
„ reticulata														*			
Carya alba								*	*	*							
Cocconeis sp.			*														
Chamaecyparis sphaeroidea									*	*							
Crataegus punctata								*		*							
Cyperaceae sp.										*					*	*	
Distichium capillaceum						*											
Drosera rotundifolia															*		
Elodea canadensis			*												*	*	
Encyonema prostratum			*												*	*	
Equisetum limosum															*		
„ scirpoides															*		
„ sylvaticum															*		
„ sp.														*			
Eriocaulon sp.								*		*							
Fontinalis sp.														*	*		
Fucus digitatus															*	*	
Fraxinus quadrangulata								*									
„ sambucifolia										*							
„ americana										*							
Festuca ovina									*	*							
Gaylussacia resinosa															*		
Gramineae sp.															*		
Hypnum commutatum														*			
„ fluitans																*	
„ recurvans						*											

Distribution of Pleistocene Plants—continued.

—	Erie Clays	Cape Breton	Rolling River, Manitoba	Solsgirth, Manitoba	Leda River, Manitoba	Moose and Missinaibi Rivers	Don Valley							Scarborough	Green's Creek	Besserer's Wharf	Montreal
							Bottom of Logan's Clay	Don River	Gaol Farm	Taylor's	Price's	Simpson's	Bend of Don				
Hypnum revolvens . .														*			
„ sp.									*								
Juniperus virginiana .									*	*			*				
Larix americana . . .						*				*	*	*		*			*
„ churchbridgensis .				*													
Licmophora sp. . .			*														
Lycopodium sp. . .						*											
Maclura aurantiaca . .								*	*	*			*				
Menyanthes trifoliata .																	*
Navicula lata . . .			*														
Oryzopsis asperifolia .															*		
Oxycoccus palustris .														*			
Picea alba														*			
„ nigra	*					*	*	*	*	*	*						*
„ sp.								*									
Pinus strobus											*						
Platanus occidentalis .								*		*							
Populus balsamifera .								*		*					*	*	
„ grandidentata .								*		*					*		*
Potamogeton pectinatus .																*	
„ perfoliatus .															*	*	
„ pusillus .															*	*	
„ rutilans .															*	*	
„ natans .										*							
Potentilla anserina . .															*	*	
Prunus sp.										*							
Quercus obtusiloba . .								*									
„ alba (?) . .									*								
„ rubra . .									*				*				
„ tinctoria . .										*			*				
„ oblongifolia .													*				
„ macrocarpa .									*	*							
„ acuminata .										*							
Robinia pseudacacia .									*	*							
Salix sp.								*		*				*			
Taxus canadensis . .		*	*	*				*									
Thuya occidentalis . .					*					*							
Tilia americana . .									*	*							
Typha latifolia . .																*	
Ulmus americana . .								*	*	*							
„ racemosa . .								*									
Vaccinium uliginosum .													*				
Vallisneria spiralis . .			*												*	*	
Zostera marina . . .																	*
Totals	1	1	7	2	1	6	1	17	14	27	3	1	5	14	24	14	7

The most easterly of the localities in the related deposits is Montreal. The majority of the specimens recovered at this point represent drift material brought down by tributary rivers, but the great abundance of *Zostera marina* and the occurrence of Algae show that some of the plants at least were deposited in place. The matrix is a blue clay. Seven species in all have been recovered from this locality, and they are all

identical with species now common in the same district—except, of course *Zostera*—thus indicating similar climatic conditions.

At Green's Creek, near Ottawa, and at Besserer's Wharf, a few miles below on the Ottawa River, numerous plant remains are found enclosed in clay nodules, but their very fragmentary character often renders their determination most unsatisfactory. These two localities, although separately treated, are in reality one and the same, since the deposit at each place is of the same nature, and was undoubtedly laid down at the same time, and they have proved to be among the richest in plant remains of all the localities studied—no less than twenty-eight species having been recovered from the clay nodules. An analysis of this flora shows 35·71 per cent. of the plants to be wholly aquatic, and therefore deposited in place. 35·71 per cent. are land plants, drifted in by tributary rivers, and 28·57 per cent. represent semi-aquatics and marsh plants from adjacent land areas. The vegetation, as a whole, is identical with that now found in the same region, from which we may infer similar climatic conditions.

At Scarborough Heights, near Toronto, the flora is rather remarkable for the complete absence of aquatic types, showing the drift character of the entire deposit. Fourteen species in all have been found there, and of these six are trees, while the remaining eight embrace mosses, equiseta, and herbaceous or half-shrubby plants. The vegetation as a whole is of a decidedly more boreal type than that now flourishing in the same region, and, if anything, somewhat more northern than that which is to be found in the deposits at Green's Creek and Montreal. This points to a climate equivalent to that of northern Quebec and Labrador, as we know it to-day, and somewhat colder than the climate at Green's Creek and Montreal during Pleistocene time.

In the Don Valley no less than eight separate localities have been examined. Some of them, as at Simpson's, proved practically barren of results so far as plant remains were concerned, owing to the uncontrollable influx of water. Others again, as at Taylor's Brickyard and the Don River, proved to be exceptionally rich in material, and afforded some of the most valuable results obtained. Within this area no less that thirty-eight species have been recovered, and they point conclusively to the existence of climatic conditions differing materially from those which now prevail, and of a character more nearly allied to that of the middle United States of to-day.

The Erie Clays at Hamilton, Ontario, have afforded only one example of plant life, and this does not materially aid us in any conclusions relative to climatic conditions, since it is a type having a somewhat wide range within the warmer zone, represented by the more southern types of the Pleistocene flora.

Only one species appears to have disappeared in Pleistocene time. *Acer pleistocenicum*, which was abundant in the region of the Don, bears no well-defined resemblance to existing species. With this one exception, it is a noteworthy fact that all the plants of the Pleistocene flora were such as are now represented in the same localities, or, in the case of the Don Valley, by plants which find the northern limits of their distribution at or near that region, and the somewhat unequal distribution thus indicated at once suggests definite climatic changes during Pleistocene time, as represented by the northern and southern migration of particular types of plants. This has already been referred to in previous reports and publications, but it may be repeated at this time that the definite and abundant occurrence of *Maclura aurantiaca*, *Juniperus virginiana*, *Quercus obtusi-*

loba, *Quercus oblongifolia*, *Asimina triloba*, *Chamaecyparis sphaeroidea*, and *Fraxinus quadrangulata* points without question to the prevalence of a much warmer climate than now prevails, while, on the other hand, the equally abundant occurrence of boreal types at Scarborough points to the existence of a colder climate at the time these deposits were laid down. It is therefore clear that in the region of Toronto during Pleistocene time there were at least two distinct periods, characterised, on the one hand, by a climate equivalent to that of the middle United States at the present day, and, on the other hand, a climate equivalent to that of northern Quebec and Labrador. According to stratigraphical evidence obtained by Professor Coleman, these changes followed the recession of the ice sheet in the order given, from which we are to conclude that the climate of the Don Valley is now intermediate between that of the first and second periods, approaching the former.

On the other hand, again, the flora of Green's Creek and Besserer's, as also that of Montreal, is practically identical with that now existing in the same localities. It thus represents a climate colder than that of the Don period, but somewhat warmer than that of the Scarborough period, but present evidence does not enable us to ascertain if these deposits were laid down before or after the Scarborough deposits. The following summary will probably assist in conveying a clearer idea of the distinctive differences in the vegetation of these three periods.

—	Don Period, Warm Climate	Scarborough Period, Cold Climate	Green's Creek Period, Mild Climate
Abies balsamea		*	
Acer pleistocenicum	*		
Acer saccharinum			*
Acer spicatum	*		
Algae sp.			*
Alnus sp.		*	
Asimina triloba	*		
Betula lutea			*
Brasena peltata			*
Bromus ciliatus			*
Carex aquatilis		*	
„ magellanica			*
„ reticulata		*	
Cara alba	*		
Chamaecyparis sphaeroidea	*		
Crataegus punctata	*		
Cyperaceae sp.	*		*
Drosera rotundifolia			*
Elodea canadensis			*
Encyonema prostratum			*
Equisetum limosum			*
„ scirpoides			*
„ sp.		*	
„ sylvaticum			*
Eriocaulon sp.	*		
Fontinalis sp.		*	*

Summary—continued.

—	Don Period, Warm Climate	Scarborough Period, Cold Climate	Green's Creek Period, Mild Climate
Fucus digitatus			*
Fraxinus quadrangulata	*		
„ sambucifolia	*		
„ americana	*		
Festuca ovina	*		
Gaylussacia resinosa			*
Gramineae sp.			*
Hypnum commutatum		*	
„ fluitans			*
„ revolvens		*	
„ sp.	*		
Juniperus virginiana	*		
Larix americana	*	*	
Lycopodium sp.		*	
Maclura aurantiaca	*		
Oryzopsis asperifolia			*
Oxycoccus palustris		*	
Picea alba		*	
„ nigra	*		
„ sp.	*		
Pinus strobus	*		
Platanus occidentalis	*		
Populus balsamifera	*		*
„ grandidentata	*		*
Potamogeton pectinatus			*
„ perfoliatus			*
„ pusillus			*
„ rutilans			*
„ natans	*		
Potentilla anserina			*
Prunus sp.	*		
Quercus obtusiloba	*		
„ alba (?)	*		
„ rubra	*		
„ tinctoria	*		
„ oblongifolia	*		
„ macrocarpa	*		
„ acuminata	*		
Robinia pseudacacia	*		
Salix sp.	*	*	
Taxus canadensis	*		
Thuya occidentalis	*		
Tilia americana	*		
Typha latifolia			*
Ulmus americana	*		
„ racemosa	*		
Vaccinium uliginosum		*	
Vallisneria spiralis			*
Zostera marina			*
Totals	38	14	29

Exploration of Irish Caves.—Interim Report of the Committee, consisting of Dr. R. F. SCHARFF (*Chairman*), Mr. R. LLOYD PRAEGER (*Secretary*), Mr. G. COFFEY, Professor GRENVILLE COLE, Professor D. J. CUNNINGHAM, Mr. A. MCHENRY, *and* Mr. R. J. USSHER.

OWING to various circumstances, especially illness of some of the members, the Committee were unable during the past year to commence the exploration of the caves in the west of Ireland. These caves promise to yield satisfactory results, and the Committee recommend that they should be reappointed, with a renewed grant of 20*l*.

Life-zones in the British Carboniferous Rocks.—Report of the Committee, consisting of Mr. J. E. MARR (*Chairman*), Dr. WHEELTON HIND (*Secretary*), Mr. F. A. BATHER, Mr. G. C. CRICK, Mr. A. H. FOORD, Mr. H. FOX, Mr. E. J. GARWOOD, Dr. G. J. HINDE, Professor P. F. KENDALL, Mr. J. W. KIRKBY, Mr. R. KIDSTON, Mr. G. W. LAMPLUGH, Professor G. A. LEBOUR, *the late* Mr. G. H. MORTON, Mr. B. N. PEACH, Mr. A. STRAHAN, *and* Dr. H. WOODWARD. (*Drawn up by the Secretary.*)

IT is to be regretted that since the meeting at Dover no individual reports have been received from members of the Committee, and that the lamellibranchs collected at Eccup only have been examined and named.

The Secretary suggests that the most important points to settle are the faunas of (*a*) the beds which occur between the Millstone Grits and the Massif of Limestone in the South Pennine area, and (*b*) the fauna which occur in the shales between the Millstone Grits and the upper beds Limestone in the North Pennine area. This would settle at once the correlation of Pendleside Limestone and its equivalent in the Yoredale series of Wensleydale.

Mr. B. N. Peach has been at work on the faunas of the Calciferous Sandstone series of Fife, and it is hoped that a full detailed report will be received next year. It would be well if a grant could be made to employ a collector to work the shales of Pendle Hill, and if possible in Swale and Teesdale.

The Committee regret to report the loss, by death, of two of their number—the late Professor Alleyne Nicholson and G. H. Morton. Mr. Morton was an ardent worker at Carboniferous geology, and had specially confined his attention to North Wales; a full list of Carboniferous fossils from this district was to have been prepared by him this year.

APPENDIX.

Interim Report by Dr. WHEELTON HIND.

In the 'Geological Magazine,' 1898, Dec. IV. vol. v. pp. 61–69, I gave a brief sketch of what was known of the Life Zones of the Carboniferous deposits of Europe, and at p. 68 showed the following table, which represented the main results of my investigations up to that date.

—	England	Scotland	Ireland
1. Zone of *Anthracomya Phillipsii*	Upper Coal-measures of Lancashire, Yorkshire, Staffordshire, Bristol, including the *Spirorbis* Limestones	The Red Beds of Fifeshire	? Wanting
2. Zone of *Naiadites modiolaris* and *Anthracomya modiolaris*	Middle Coal-measures universally	The Coal-measures of Fifeshire	Coal-measures
3. Zone of *Aviculopecten papyraceus, Gastrioceras carbonarium, Posidoniella lævis*, and *P. minor*	Ganister Series Millstone Grit Shales below the Millstone Grit universally	? Wanting NOTE.—*Aviculopecten papyraceus* is said to be found some distance above the Ell Coal in the Wishaw district, Lanarkshire	Castlecomer, Leinster Coalfield Coal-measures of Foynes island, co. Limerick
4. Zone of *Productus giganteus* and *Productus cora*	The Carboniferous Limestone of Derbyshire The measures from the Great Scar to the Main Limestone, N. Yorkshire The Carbonaceous Division of Northumberland Carboniferous Limestone of Wales and the Mendips	The Carboniferous Limestone Series of Scotland { Upper, Middle, Lower	The Upper Limestone The Calp The Lower Limestone
5. Zone of *Modiola Macadamii*	The Lower Limestone Shales of the Mendips and South Wales, with several fossils common to the Old Red Sandstone Series and the Carboniferous	The Calciferous Sandstone Series, with *Schizodus Pentlandicus* and *Sanguinolites Abdensis* in Fifeshire, and a fauna very different from the English and Irish equivalents. Mr. Kirkby states that *Productus cora* is contained in the upper 500 feet of these beds	The Coomhola and Moyola beds, forming a passage from the Old Red to the Carboniferous, and containing certain fossils common to both

Series 1–3 constitute what I consider to be the 'Upper Carboniferous,' and series 4 and 5 the 'Lower Carboniferous,' of my paper on the Yoredale Series.[1]

[1] *Geol. Mag.*, April and May 1897.

Further work has convinced me of the correctness of these main zonal divisions, and observations on the subdivision of the lower part of Zone 3 are approaching to some degree of exactness.

With regard to the subdivision of group 4 I am in hopes that *Edmondia sulcata* and *Allorisma monensis* may be found to indicate an horizon in Zone 4; but as yet these fossils have not been found in the South Pennine area.

I consider interesting the discovery of *Cypricardella rectangularis*, *C. Annæ*, *Nuculania attenuata*, *Ctenodonta sinuosa*, and other shells in shale above the Underset Limestone, nine standards near Kirkby Stephen, and a very similar fauna at the same horizon on Wild Boar Fell. *C. rectangularis* with an identical fauna is found to be common in the Lower Limestone. Series of Strathavon and the Upper Limestone series of Orchard near Glasgow:—a full description of the section and position of the fossiliferous beds was published at p. 358 in Part IV. of my monograph on 'British Carboniferous Lamellibranchs,' 1899.

Registration of Type Specimens of British Fossils.—Report of the Committee, consisting of Dr. H. WOODWARD (*Chairman*), Rev. G. F. WHIDBORNE, Mr. R. KIDSTON, Professor H. G. SEELEY, Mr. H. WOODS, *and* Dr. A. S. WOODWARD (*Secretary*).

DURING the past year the Committee have received a list of type-fossils in the Norwich Museum, compiled by Mr. Frank Leney. The Museum of Practical Geology, Jermyn Street, has published a first instalment of a list of the type-fossils contained in its collections ('Type Specimens of Eocene and Oligocene Fossils,' by H. A. Allen, appended to the Annual Report of the Geological Survey of Great Britain for 1899).

Ossiferous Caves at Uphill.—Report of the Committee, consisting of Professor LLOYD MORGAN (*Chairman*), H. BOLTON (*Secretary*), Professor W. BOYD DAWKINS, Professor S. H. REYNOLDS, *and* E. T. NEWTON.

THE excavation work of last year was continued until the approach of winter, by which time the lower caves were worked out, nothing new being added to the discoveries reported to the Association at the Dover meeting.

The caves were found to lie along the bedding planes of the limestone, and had clearly formed part of a subterranean drainage system, the material in them being derived presumably from caves on higher levels.

Systematic search has been made for caves of habitation higher up the hill, but hitherto with no success.

Work has therefore been arrested. It is hoped to secure a visit and report from Professor Boyd Dawkins before further exploratory work is commenced.

The Committee have, up to the present, incurred an expenditure of 45*l*. 14*s*. 2*d*., 30*l*. of which has been met by the grant made in 1898 at Bristol.

The Committee do not feel justified in requesting a grant for future work, but they seek reappointment with a grant of 10*l.* (the sum not claimed last year) to cover expenses already incurred. It is their intention to further examine the ground as quarrying proceeds.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Professor E. HULL (*Chairman*), Mr. P. F. KENDALL (*Secretary*), Professor T. G. BONNEY, Mr. C. E. DE RANCE, Professor W. J. SOLLAS, Mr. R. H. TIDDEMAN, Rev. S. N. HARRISON, Mr. J. HORNE, Mr. F. M. BURTON, Mr. J. LOMAS, Mr. A. R. DWERRYHOUSE, Mr. J. W. STATHER, *and* Mr. W. T. TUCKER. (*Drawn up by the Secretary.*)

THE records of boulders observed during the past year have been derived principally from Yorkshire, thanks to the activity of the local organisation which has for so many years occupied itself with the investigation; but the Committee is hopeful that other areas may be subjected to an equally stringent examination. Work had been commenced in the county of Durham under the stimulus of an enthusiastic worker, the late Dr. Taylor Manson, of Darlington; and though the Committee has to deplore his removal by death before any definite results were obtained, it is expected that the movement which he initiated will be productive of valuable contributions to the knowledge of a rich and scarcely touched field.

An important advance affecting much of the eastern side of England, and particularly the counties of Northumberland, Durham, and Yorkshire, is marked by a visit paid to the Cheviot country by the Yorkshire Geological and Polytechnic Society at the instigation of members of the Boulder Committee of the county. The object of this excursion was to study the igneous rocks of the Cheviots, with a view to the recognition of any erratics of similar types, and to determine how far the ascription to this source was correct of a series of porphyrites which form a very considerable proportion of the far travelled boulders of Yorkshire. It was found that an even larger number of types of erratics could be traced to the Cheviots than had been anticipated. A large number of specimens were collected, and the Secretary of this Committee will be glad to furnish sets of examples to any geologists willing to assist in the investigation of the boulders of the East of England.

A very important further result was obtained from the excursion. In the report for 1897 reference was made to the identification by Professor Brögger of the Sparagmite Sandstone of Scandinavia in a series of Yorkshire erratics submitted to him. In subsequent reports occurrences of a similar rock in various localities in Yorkshire have been mentioned, but some doubt has been felt regarding the identification, and all such records have been given with a '?'.

This caution has been justified by the discovery that a sandstone precisely resembling some of the erratics of Yorkshire constitutes a significant proportion of the stones in the 'foreign' drift of the country about Wooler and Ingram in the Cheviots. It is referred to in the Geological Survey Memoirs of the district under the name of 'Greywacke Sandstone,' and its source is given as in the Silurian area of the Tweed Valley.

A further extension of the known distributions of Shap Granite blocks is furnished by the example reported from Gainsborough, and the interesting Riebeckite-Eurite of Ailsa Craig has been recorded from Delamere, in the very heart of Cheshire.

Cheshire.

Reported by Mr. J. Lomas, *A.R.C.S.*, *F.G.S.*

Birkenhead.—In cutting a sewer in Woodchurch Road, near Half-way House, Boulder Clay about 25 feet thick; boulder of diabase 3 feet diameter.

Delamere Forest.—Great spreads of sands and gravels. Group near station contains Lake District andesites, Eskdale and Criffel granites. Riebeckite-Eurite from Ailsa Craig. Flints.

Shropshire.

Church Stretton, Watling Street—

Criffel granite, 1 foot diameter.
Eskdale granite.

Gravel Pit under Hazler Coppice, 800 ft. O.D.—

Eskdale granite.
Buttermere granophyre.
Permian sandstone from north.

Comley—

Eskdale granite.

All Stretton—

Triassic sandstone.

North Wales.

Llandrillo, near Bala.—Section of Drift nearly 100 feet high, cut by stream near Cadwst, full of large boulders, many over 6 feet in diameter. Nearly all ash and greenstone; exposures of similar rocks a little distance southwards.

Greenstones increase in number on following up the stream Nant-cwm-Dywyll as far as the firwood. To the east the ground is strewn with large clusters of greenstone boulders. On the summit of the rising ground the rock is found *in situ*, and shows *roches moutonnées* and striations from the south. No greenstone boulders are found in the low ground south of the outcrop.

Old Slate Quarry S. of Carnedd-y-ci.—Many quartzite and greenstone boulders of large size resemble rocks found *in situ* on Cader Berwyn, immediately to the south.

Glyn Ceiriog.—Group of boulders in field just above cottage called Pant. Some over 5 feet in diameter consist of Welsh felsites and Denbigh grits. The grits, which are fossiliferous and beautifully striated, occur *in situ* to the north and west. On the hills to the south of Glyn Ceiriog, Denbigh grits occur as boulders up to 1,250 feet.

Yorkshire.

Reported by the Yorkshire Boulder Committee (Mr J. H. Howarth, *F.G.S., Secretary*).

By Mr. H. H. Corbett, *M.R.C.S., of Doncaster.*

Cushworth.

1 Dolerite.

By Mr. P. F. Kendall.

Barugh Hill, near Robin Hood's Bay.—Many boulders of porphyrite and two examples of a very coarse pisolite containing *Nerinæa.*

Thirley, near Cloughton.—Great gravel-mounds here are strewn with large blocks, all of Jurassic sandstone, in numbers greatly exceeding what may be seen elsewhere in Yorkshire.

Whitby—Cliffs to West of Town.—A bed of gravel lying between two beds of Boulder Clay, the lower dark grey in colour, the upper reddish, contains the following rocks roughly in order of prevalence: Jurassic and other sandstones, Magnesian Limestone, Carboniferous Limestone, basalt, conglomerate (? Sparagmite), Greywacke sandstone (or ? Sparagmite), jasper, Alum Shale (a large block), Gryphæa incurva, ball of red Boulder Clay.

Wheatcroft, near Scarborough.—In corner of second field W. of road, Shap granite 2 feet long.

Seamer.—The gravels between Seamer Quarries and Waydale House contain very high proportion of basalts.

Seamer Beacon.—The tower here is built of rough blocks, mainly of Jurassic sandstone, but with large numbers of basalt or dolerite and some Cheviot porphyrite.

Yedmondale.—A pit shows gravel consisting of local stones with many Cheviot porphyrites, some Greywacke, jasper, and a few granite pebbles. Fragmentary marine shells are also found.

Hutton Bushel.—In gravel pit on 200 feet contour. Many local stones with Cheviot porphyrites, Magnesian Limestone (Roker type), Kimeridge clay, gneiss, granite.

Reported by Boulder Committee of the Hull Geological Society.

By Mr. Thos. Sheppard, *F.G.S.*

Burstwick Gravel Pit, Holderness—

Shap granite, 8 in. by 6 in.
Rhomb-porphyry, 4 in. by 4 in.

By Mr. J. W. Stather, *F.G.S.*

Atwick.—At the foot of cliffs—

Shap granite, 18 in. by 20 in. by 14 in.
Augite-syenite (Laurvikite) 18 in. by 18 in. by 12 in.
Rhomb-porphyry, several pebbles.

Fordon on the Wolds.—250 feet O.D.—

Gneiss, 24 in. by 12 in. by 12 in.
Basalt, 30 in. by 24 in. by 24 in., planed on one side.
Carboniferous sandstone, 24 in. by 12 in. by 12 in.

Kirkmoorgate, near Robin Hood's Bay.—600 feet O.D.—

Rhomb-porphyry, 7 in. by 4 in. by 4 in.
Also two smaller pebbles of same.

Peake—Yorkshire Coast—600 feet O.D.—

In thick glacial gravel, quarry above railway station. Shap granite 18 in. by 15 in. by 12 in.
Rhomb-porphyry. Four small boulders.

Runswick Bay—

1 Shap granite, 30 in. by 24 in. on the beach near the village.
2 ,, 66 in. by 48 in. by 36 in. on the beach near the village.
3 Brockram, 12 in. by 8 in.
4 Magnesian Limestone, 60 in. by 48 in. by 36 in.
5 Shap granite, 24 in. by 24 in. by 18 in.
6 ,, 48 in. by 36 in.
7 ,, 36 in. by 48 in.

This group, with probably many others, in the bed of the largest of the four or five becks which run into the bay.

Speeton—

Shap granite, 12 in. by 8 in. by 8 in.

Stump Howe—

8 miles west of Whitby. 650 feet O.D.
Rhomb-porphyry.
A pebble.

LINCOLNSHIRE.

Reported by Mr. J. A. JORDAN, *of Doncaster.*

Gainsborough.—On Spital Hill—

Large block of Shap granite, the light variety.
Block of 'Greenstone' (probably dolerite).

NORTHUMBERLAND.

Reported by Mr. P. F. KENDALL.

Akeld, near the ruins of castle—

Gravel, comprised largely of porphyrite with some Silurian Greywacke.

Calder Farm, Roddam Dene—

Porphyrite and Greywacke.

The Movements of Underground Waters of Craven.—First Report of the Committee, consisting of Professor W. W. WATTS (*Chairman*), Mr. A. R. DWERRYHOUSE (*Secretary*), Professor A. SMITHELLS, Rev. E. JONES, Mr. WALTER MORRISON, Mr. G. BRAY, Rev. W. LOWER CARTER, Mr. T. FAIRLEY, Mr. P. F. KENDALL, *and* Mr. J. E. MARR. (*Drawn up by the Secretary.*)

THE Committee is carrying out the investigation in conjunction with a Committee of the Yorkshire Geological and Polytechnic Society.

The present is merely an interim report, as the work is still in progress.

It was decided that the first piece of work should consist of an investigation of the underground flow of water in Ingleborough. This hill forms with its neighbour, Simon's Fell, a detached massif, which is peculiarly suitable for investigations of this nature.

The summit of the group is formed of Millstone Grit, then follow Yoredale Shales and Sandstones, the whole resting on a plateau of Carboniferous Limestone.

Many streams rise on the upper slopes of the hills and flow over the Yoredales, but without exception their waters are swallowed directly they pass on to the Carboniferous Limestone, to reappear as springs in the valleys which trench the plateau.

The Committee first turned its attention to tracing the water which flows into Gaping Ghyll.

It was generally believed that the water issued at a large spring immediately above the bridge at Clapham Beck Head and immediately below the entrance to Ingleborough Cavern.

On April 28 specimens of the water from this spring were taken for analysis before the introduction of any test.

Two cwt. of ammonium sulphate was then put into the water flowing into Gaping Ghyll, and at the same time the amount of the water was gauged and found to be equivalent to 251,856 gallons per diem. A few hours later a second quantity of two cwt. of the same substance was introduced.

On the same day $1\frac{1}{2}$ lb. of fluorescein in alkaline solution was put into a pot-hole known as Long Kin East, about 1,300 yards north-east of Gaping Ghyll.

In view of the important influence which the direction of the joints in the limestone had been found to exercise over the flow of underground water,[1] the direction of the joints in the limestone clints in the neighbourhood of Long Kin East was taken, and was found to be N.N.W. to S.S.E., and to run in such a direction as to lead to the probability that the water would reappear at the springs at the head of Austwick Beck, and these were consequently watched.

The ammonium sulphate put in at Gaping Ghyll reappeared at the large spring at Clapham Beck Head on the morning of May 3, and continued to flow until the evening of May 6, when the water again became normal. Thus the time occupied by the ammonium sulphate in travelling from Gaping Ghyll to Clapham Beck Head, a distance of one mile, was about five days.

No ammonium sulphate was found in any of the other springs in Clapdale.

This result proved beyond doubt that Gaping Ghyll was connected with Clapham Beck Head.

The fluorescein put in at Long Kin East showed itself at Austwick Beck Head, but not at any of the neighbouring springs, on May 11, having taken over thirteen days to travel, the delay being probably due to the small amount of water flowing at the time of the experiments.

These results are of considerable importance, as they definitely reveal two lines of divergent movement of these underground waters, and indicate a subterranean watershed of much interest. The influence of the master-joints of the Carboniferous Limestone in determining the direction of flow of these underground waters was also, as at Malham, clearly shown.

The next set of experiments was carried out by the joint Committee on June 8 and following days.

In order to confirm the results in connection with the Gaping Ghyll to Clapham Beck Head flow, and further to ascertain more definitely if

[1] See previous investigations of the Yorks. Geol. and Poly. Soc. Committee.

there existed any connection between Gaping Ghyll and the smaller springs in Clapdale, 10 cwt. of common salt was put into the waters of Gaping Ghyll on June 4, and a further 10 cwt. on June 5, samples of the water from each of the springs being taken several times a day until June 25.

One pound of fluorescein in alkaline solution was introduced into the stream flowing through Ingleborough Cave on June 8 at 10 P.M., at the point where the water plunges down a hole in the floor of the cave, and marked 'Abyss' in the 6-inch Ordnance map.

Five cwt. of ammonium sulphate was introduced into a sink on The Allotment about 500 yards N.E. of Long Kin East on June 9, at 3 P.M.; and at 3.15 P.M. on the same day 1 lb. of fluorescein in alkaline solution was poured into the stream which flows past the shooting-box on The Allotment and sinks near the Bench Mark 1320·1.

The fluorescein introduced into the abyss came out at Clapham Beck Head, and possibly at Moses Well and other springs in Clapdale, but this point requires further investigation, the evidence being as yet somewhat unsatisfactory.

The salt from Gaping Ghyll appeared at Clapham Beck Head on June 15, 16, 17, 18, 19, 20, and 21, being at its maximum on June 18, but not at any of the other springs.

The ammonium sulphate put into the sink on The Allotment appeared at Austwick Beck Head on June 22, the other springs in the neighbourhood being unaffected on that day; but on the 24th and 25th there were slight increases in the amount of ammonia in two small springs in Clapdale, viz. the small spring below Clapdale Farm, and Cat Hole Sike. As one of these streams is close to the farmyard, and the other was at the time nearly dry and flowing through pasture-land, no importance is attached to these slight increases.

Of the fluorescein put in below the shooting-box no trace has since been found, and the same is the case with ½ lb. of methylene blue introduced into Grey Wife Sike, above Newby Cote.

Several most interesting problems still await solution in this area, one of them being the relations of the Silurian floor, which underlies the Carboniferous Limestone of the plateau, to the flow of underground water.

The two sinks Gaping Ghyll and Long Kin East are only about 1,300 yards apart, and yet the waters of the one take a direction quite distinct from those of the other, and eventually emerge in a separate valley, the distance between the springs being 1½ miles, the great mass of Carboniferous Limestone known as Norber, a hill upwards of 1,300 feet in height, lying between the two valleys.

In Crummack Dale it is seen that the Silurian rocks form a ridge running in an approximately N.W. and S.E. direction, and unconformably overlain by the Carboniferous Limestone.

If this line be continued it separates the Gaping Ghyll to Clapham Beck Head flow from that of Long Kin East to Austwick Beck Head.

Thus it appears that this ridge of Silurian rocks forms an underground water-parting, which the Committee hopes to be able to trace further across the area.

The magnitude of this undertaking will be to some extent realised when it is stated that upwards of 400 samples of water have been tested for common salt, ammonia, and fluorescein, making in all upwards of 1,200 tests.

The whole of the grant of 40*l.* has been spent upon the investigation, and a small sum in addition.

The experiments which have been carried out have indicated which are the most suitable reagents for use in different cases, and it is consequently hoped that future investigations will be carried out at rather less cost than has been the case up to the present.

The Committee asks to be reappointed, with a grant of 60*l.*

Irish Elk Remains.—Fourth Report of the Committee, consisting of Professor W. BOYD DAWKINS (*Chairman*), *the late* Deemster GILL, Rev. Canon SAVAGE, Mr. G. W. LAMPLUGH, *and* Mr. P. M. C. KERMODE (*Secretary*), *appointed to examine the Conditions under which Remains of the Irish Elk are found in the Isle of Man. (Drawn up by the Secretary.)*

THE Committee deeply regret the loss in October last of one of their number, Deemster Gill, by whose pressing desire it was that the first excavation was made near St. John's in 1897, when their efforts were rewarded by the discovery of the perfect skeleton of 'Irish Elk' now in Castle Rushen.[1]

The following paragraph was added to our last report after it was in type, and the bone in question exhibited at our Dover meeting, but by some accident it was omitted from the report as published, so we insert it here. 'At a depth of about nine feet below the surface, at the bottom of the silt (Bed C of our first report), and just above the white Chara-marl, were found two fragments of bone, which were forwarded to our Chairman, who has identified one as the scapula of *Bos longifrons*, and in a letter to the Secretary adds: "This establishes the presence in the island of an animal which was domesticated and introduced into the British Isles in the Neolithic age. It proves that this deposit in which it occurs is not earlier than the Neolithic age."'

At the end of October last another trench, 12 yards by 3, was cut across the Loughan ruy, Ballaugh,[2] parallel to and about 2 yards north-west of that of last year. At a point about 4 yards from the north-east end the marl was found at a depth of 10 feet 3 inches, just over a foot deeper than in last year's trench, showing the dip towards the north-west.

In the peat, which extended from the surface to a depth of 3 feet, were several pieces of timber, the largest being about 15 inches diameter at the root: this bed rested upon silt, which extended to a further depth of 7 feet. It varied slightly in different parts, here more sandy, there more loamy, but was really all one bed, the bottom of which consisted chiefly of small flat water-worn stones. At a depth in this bed of 6 feet, that is to say, about 9 feet from the surface, was a layer of leaves about half an inch thick.

In this layer, on the south-east side of the trench, about 3 yards from its south-west end, was found a fragment of antler, thickly covered with the blue phosphate which appears to be confined to this leaf-deposit. All around it were minute decayed fragments of bone or antler.

Three or four yards away, at a depth of 10 feet from the surface,

[1] See Report, 1898. [2] *Ibid.*, 1897.

being about 3 inches from the white marl bed, but distinctly in the silt, was another fragment of antler: this was in the north-west side of the trench, and about a yard from its south-west end.

The marl was struck at a depth of 10 feet to 10 feet 3 inches; and at a point from 9 to 12 inches within it, that is to say, about 11 feet below the present surface, there was still another antler fragment, some 3 yards further south-east than the last, in the south-west end of the trench. Immediately below this the marl was bluish black, exactly as it was round the head of the skeleton found near St. John's (Close-y-Garcy). This darkened marl was from 9 to 10 inches thick, and extended over an area from the south-west end of the trench of about 3 feet square. All through it were crumbs of decayed bones, doubtless 'Irish Elk.'

Photographs of Geological Interest in the United Kingdom.—Tenth Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Professor T. G. BONNEY, Dr. TEMPEST ANDERSON, Mr. GODFREY BINGLEY, Mr. H. COATES, Mr. C. V. CROOK, Mr. E. J. GARWOOD, Mr. J. G. GOODCHILD, Mr. WILLIAM GRAY, Mr. ROBERT KIDSTON, Mr. A. S. REID, Mr. J. J. H. TEALL, Mr. R. WELCH, Mr. H. B. WOODWARD, Mr. F. WOOLNOUGH, *and* Professor W. W. WATTS (*Secretary*). (*Drawn up by the Secretary.*)

THE Committee have the honour to report that during the year 309 new photographs have been received, bringing the total number in the collection to 2,655.

In addition to this 12 prints and 10 slides have been given to the duplicate collection, making a total of 331 photographs received during the year.

Five misplaced prints have been renewed by the kindness of Miss Andrews, Mr. Brown, Mr. Coomara-Swamy, and Mr. Bingley.

The usual scheme showing the geographical distribution of photographs is appended. There are no new counties in the list except Anglesey and Meath, but the following counties are now much better represented than hitherto:—Buckingham, Essex, Gloucester, Somerset, Pembroke, Inverness, and Clare. The scheme of the main collection has been most carefully checked with the prints, catalogues, and printed lists, all doubtful numbers have been weeded out, and it may be taken to represent accurately the actual state of the collection. For this reason it is not quite consistent with previous schemes, when these precautions have not been possible. Three photographs have been assigned to old numbers, namely, 191, 399, and 400, and the missing photographs hitherto assigned to these numbers cancelled.

Mr. A. S. Reid has continued his photographic survey of the Island of Eigg and contributed a set of photographs taken there.

Mr. Greenly sends a valuable set of photographs taken under the auspices of a Committee of the Association in order to preserve a reliable and unbiassed record of the disappearing sections of elevated drifts on Moel Tryfaen, in Carnarvonshire.

Mr. Coomara-Swamy contributes a considerable series taken on the mainland of Inverness and in Skye.

Mr. S. H. Reynolds has illustrated the recent work of himself and Mr. Gardiner at Clogher Head with a group of admirable photographs, and he also sends groups from the areas of Clifton, Bath, and the Dorsetshire coast. Mr. Monckton also contributes photographs from the last district and several others.

—	Previous collection	Additions (1900)	Total	Duplicates			
				Previous collection	Additions (1900)		Total
					Prints	Slides	
ENGLAND—							
Bedfordshire	3	1	4	—	—	—	—
Berkshire	3	—	3	—	—	—	—
Buckinghamshire	4	3	7	1	—	—	1
Cheshire	46	—	46	12	—	—	12
Cornwall	37	5	42	3	—	—	3
Cumberland	8	—	8	—	—	—	—
Derbyshire	27	3	30	1	—	—	1
Devonshire	122	4	126	8	2	3	13
Dorset	59	31	90	6	—	2	8
Durham	27	2	29	1	—	—	1
Essex	1	2	3	—	—	—	—
Gloucestershire	15	9	24	1	—	—	1
Hampshire	19	—	19	1	—	—	1
Herefordshire	1	—	1	—	—	—	—
Hertfordshire	10	—	10	—	—	—	—
Kent	67	3	70	13	—	—	13
Lancashire	60	7	67	10	—	—	10
Leicestershire	93	—	93	20	—	—	20
Lincolnshire	1	3	4	—	—	—	—
Middlesex	3	—	3	—	—	—	—
Monmouth	5	—	5	2	—	—	2
Norfolk	16	2	18	7	—	—	7
Northamptonshire	6	—	6	—	—	—	—
Northumberland	41	1	42	—	—	—	—
Nottinghamshire	12	1	13	1	—	—	1
Oxfordshire	1	—	1	—	—	—	—
Shropshire	29	4	33	8	—	—	8
Somersetshire	39	8	47	9	—	—	9
Staffordshire	42	—	42	10	—	—	10
Suffolk	10	—	10	—	—	—	—
Surrey	24	11	35	3	—	—	3
Sussex	9	1	10	—	—	—	—
Warwickshire	36	—	36	3	—	—	3
Westmoreland	56	5	61	6	—	—	6
Wiltshire	1	—	1	—	—	—	—
Worcestershire	14	—	14	1	—	—	1
Yorkshire	414	32	446	60	6	1	67
Total	1361	138	1499	187	8	6	201
WALES—							
Anglesey	—	5	5	—	—	—	—
Carnarvon	63	11	74	24	—	—	24

—	Previous collection	Additions (1900)	Total	Duplicates			
				Previous collection	Additions (1900)		Total
					Prints	Slides	
Denbigh . .	16	—	16	5	—	—	5
Flint . .	5	—	5	—	—	—	—
Glamorgan .	12	—	12	3	—	—	3
Merioneth .	19	—	19	5	—	—	5
Montgomery .	10	11	21	6	—	—	6
Pembroke .	1	—	1	—	—	—	—
Radnor . .	20	—	20	—	—	—	—
Total . .	146	27	173	43	—	—	43
CHANNEL ISLANDS . .	15	—	15	—	—	—	—
ISLE OF MAN .	53	7	60	4	—	—	4
SCOTLAND—							
Aberdeen .	6	—	6	—	—	—	—
Argyll . .	20	—	20	1	—	—	1
Ayr. . .	6	—	6	5	—	—	5
Banff . .	4	—	4	1	—	—	1
Berwick . .	4	—	4	1	—	—	1
Bute . .	6	—	6	—	—	—	—
Caithness .	4	—	4	2	—	—	2
Edinburgh .	47	—	47	10	—	—	10
Elgin . .	9	—	9	9	—	—	9
Fife . .	24	—	24	7	—	—	7
Forfar . .	7	—	7	—	—	—	—
Haddington .	4	—	4	1	—	—	1
Inverness .	72	42	114	28	1	3	32
Kirkcudbright	3	—	3	—	—	—	—
Lanark . .	7	—	7	5	—	—	5
Linlithgow .	2	—	2	—	—	—	—
Orkney . .	1	—	1	—	—	—	—
Perth . .	20	—	20	3	—	—	3
Renfrew . .	1	—	1	—	—	—	—
Stirling .	15	—	15	2	—	—	2
Sutherland .	6	—	6	2	—	—	2
Total . .	268	42	310	77	1	3	81
IRELAND—							
Antrim . .	195	31	226	29	1	—	30
Armagh . .	2	—	2	—	—	—	—
Cavan . .	1	—	1	—	—	—	—
Clare . .	8	5	13	—	—	—	—
Cork . .	2	—	2	—	—	—	—
Donegal . .	39	5	44	2	1	—	3
Down . .	71	15	86	16	—	—	16
Dublin . .	27	—	27	3	—	—	3
Fermanagh .	4	—	4	1	—	—	1
Galway . .	28	1	29	3	—	—	3
Kerry . .	10	16	26	—	—	—	—
Limerick .	1	1	2	—	—	—	—
Londonderry .	22	1	23	1	—	—	1
Louth . .	1	—	1	—	—	—	—

—	Previous collection	Additions (1900)	Total	Duplicates: Previous collection	Duplicates: Additions (1900): Prints	Duplicates: Additions (1900): Slides	Duplicates: Total
Mayo	14	—	14	1	—	—	1
Meath	—	2	2	—	—	—	—
Sligo	2	2	4	—	—	—	—
Tipperary	1	—	1	—	—	—	—
Total	428	79	507	56	2	—	58
Rock Structures, &c	75	16	91	31	—	—	31
Foreign	—	—	—	27	1	1	29
England	1361	138	1499	187	8	6	201
Wales	146	27	173	43	—	—	43
Channel Islands	15	—	15	—	—	—	—
Isle of Man	53	7	60	4	—	—	4
Scotland	268	42	310	77	1	3	81
Ireland	428	79	507	56	2	—	58
Rock Structures	75	16	91	31	—	—	31
Foreign	—	—	—	27	1	1	29
Total	2346	309	2655	425	12	10	447

Mr. Bingley continues to illustrate the history of the rivers of Yorkshire and the geology of the underground waters of that county.

Mr. Welch sends thirty-three beautiful platinotypes taken in Antrim, Donegal, Down, Galway, Meath, and Sligo.

Special mention should also be made of the interesting Skomer Island photographs of Mr. Small, the Irish ones of Miss Andrews, Mr. Gray, and Dr. Fogerty; those from the Lake district by Lord Avebury and from the Isle of Man by Sir Archibald Geikie; those illustrating a paper of Dr. Blanford by Mr. H. R. Blanford; and the contributions of Mr. Pledge, Mr. Tucker, and the Hull Geological Society.

To the persons already named, and to Mr. Garwood, Mr. Hollingworth, Mr. Cobbold, Mr. Davies, Mr. Lamplugh, Mr. Trevor Owen, the Yorkshire Naturalists' Union, the Belfast Naturalists' Field Club, and Mr. Midgley the thanks of the Committee are due; the last-named has sent a considerable series of micro-photographs for selection, together with a series of views.

The members of the Yorkshire Geological and Polytechnic Society, and especially Mr. Tate, have conferred a signal service on the Committee by giving details of the Coal-measure sections taken some years ago by Mr. Branson in the Leeds brickyards. The sections have been measured, and each individual bed marked and numbered on the photographs by Mr. Tate.

The duplicate collection has not received so many accessions as usual, chiefly because it is very fairly representative already. The additions to it during the year, and some others which have not yet been acknowledged,

are given in List III. Twelve prints and ten slides have been received, and the whole collection now numbers 336 prints and 111 slides. A list of donors to this collection is appended to the list, and to each of them the Committee express their thanks.

The duplicate collection has been sent to the following Societies during the year :—The Limerick Field Club, the Leeds Geological Association, the Yorkshire Philosophical Society, the South-Eastern Union of Scientific Societies, the Faraday Society of the Morley Memorial College, and the annual conversazione of the Birmingham Philosophical and Natural History Society.

A request was received from the Science and Art Department that the Committee would exhibit a typical series of geological photographs at the Paris Exhibition. An appeal was sent to photographers, who responded with their usual readiness. A small set was got together and sent to Paris, where it is now exhibited. It has received the award of a silver medal in Class XII. The following contributed prints or lent negatives for this purpose :—Mr. R. Welch, Mr. Godfrey Bingley, Mr. A. Strahan, Mr. C. A. Defieux, Mr. C. J. Watson, Mr. A. A. Armstrong, Mr. A. K. Coomara-Swamy, Mr. A. S. Reid, Mr. R. McF. Mure, Mr. H. L. P. Lowe, Dr. F. J. Allen, Mr. W. Jerome Harrison, and Mr. W. T. Tucker.

The question of publishing a typical series of geological photographs has been considered by the Committee, and as a sufficient number of subscribers has been obtained it has been decided to proceed to the issue of twenty photographs annually for three years, both as prints and lantern slides. A committee of selection, consisting of Professor Bonney, Mr. Garwood, Dr. Mill, Mr. Teall, Mr. H. B. Woodward, and the Secretary, has made a provisional selection of representative photographs. It is hoped that the first set may be issued within the year. The subscribers' list includes a large number of foreigners and colonials. The list will be closed on September 12, 1900.

Applications by local societies for the loan of the duplicate collection should be made to the Secretary. Either prints or slides, or both, can be lent, with a descriptive account of the slides. The carriage, and the making good of any damage to slides or prints, are expenses borne by the borrowing society.

ELEVENTH LIST OF GEOLOGICAL PHOTOGRAPHS.

(To August 25, 1900.)

This list contains the geological photographs which have been received by the Secretary of the Committee since the publication of the last Report. Photographers are asked to affix the registered numbers, as given below, to their negatives for convenience of future reference. Their own numbers are added in order to enable them to do so.

Copies of photographs desired can, in most instances, be obtained from the photographer direct, or from the officers of the Local Society under whose auspices the views were taken.

The price at which copies may be obtained depends on the size of the print and on local circumstances over which the Committee have no control.

The Committee *do not assume the copyright of any photographs* included in this list. Inquiries respecting photographs, and applications

for permission to reproduce them, should be addressed to the photographers direct.

The very best photographs lose half their utility, and all their value as documentary evidence, unless accurately described; and the Secretary would be grateful if, whenever possible, such explanatory details as can be given were written on the forms supplied for the purpose, and *not on the back of the photograph or elsewhere.* Much labour and error of transcription would thereby be saved. A local number by which the print can be recognised should be written on the back of the photograph and on the top right-hand corner of the form.

Copies of photographs should be sent *unmounted* to W. W. Watts, Mason University College, Birmingham, and forms may be obtained from him.

The size of photographs is indicated as follows :—

L = Lantern size.	1/1 = Whole plate.
1/4 = Quarter-plate.	10/8 = 10 inches by 8.
1/2 = Half-plate.	12/10 = 12 inches by 10, &c.

E signifies Enlargements.

* indicates that photographs and slides may be purchased from the donors, or obtained through the address given with the series.

LIST I.

ACCESSIONS IN 1899-1900.

ENGLAND.

BEDFORD.—*Photographed by* H. C. McNEILL, 29 *North Villas, Camden Square, N.W.* 1/4.

Regd. No.			
191	( )	Gas House, Leighton Buzzard	False-bedding in Lower Greensand. 1897.

BUCKINGHAM.—*Photographed by* J. H. PLEDGE,* 115 *Richmond Road, N.E.* 1/2.

2416	(B 13)	South Windmill, Long Crendon.	'Shotover Sands.' 1899.
2417	(B 11)	Littleworth Brickyard, Wing, Leighton Buzzard.	Drift. 1899.
2418	(B 12)	Warren Farm, Stewkley	Northernmost exposure of typical Portland Beds in England. 1899.

CORNWALL.—*Photographed by* A. E. MURRAY, *St. Clare, Upper Walmer, Kent.* 5/4.

2419	(7 *c*)	Constantine's Bay . .	Raised Beaches? 1897.
2420	(9 *c*)	" " . .	" "
2421	(32 *c*)	" " . .	" "
2422	(33 *ca*)	Constantine's Church .	Church surrounded by sand-dunes.
2423	(33 *cb*)	" " .	" " "

DERBYSHIRE.—*Photographed by* EVAN W. SMALL, *The Mount, Radbourne Street, Derby.* 1/1 E.

2500	(D 991)	L. & N. W. R. cutting, Tissington.	Anticline in Carboniferous Limestone. 1899.
2501	(D 992)	L. & N. W. R. cutting, Tissington.	Syncline in Carboniferous Limestone. 1899.

Photographed by W. W. MIDGLEY, *The Chadwick Museum, Bolton.* 1/2.

Regd. No.		
2634	(229) Lion's Head Rock, E. side of River Dove . . .	Crag of Carboniferous Limestone. 1900.

DEVONSHIRE.—*Photographed by* A. K. COOMARA-SWAMY, *Walden, Worplesdon, Guildford.* 1/1 E.

2424	( ) Hound Tor, Dartmouth .	Granite, jointed and weathered. 1900.
2425	( ) Cockington Beach, near Bideford.	Anticline in Culm Measures. 1900.
2426	( ) Cockington Beach, near Bideford.	" " "

Photographed by H. PRESTON, *Waterworks, Grantham.* 1/2.

399	( ) Bowerman's Nose, Dartmoor.	Jointed and weathered granite. 1900.

DORSET.—*Photographed by* H. W. MONCKTON, 10 *King's Bench Walk, Temple, E.C.* 1/4.

2429	(1327) Near Grange Gate, Creech Grange.	Working of pipe-clay of Bagshot age 1899.
2430	(1328) Corfe Castle . . .	U. M. and L. Chalk. 1899.
2431	(1329) " . . .	" " "
2432	(1330) " . . .	" " "
2433	(1334) Studland Bay . .	Reading Beds resting on Chalk. 1899.
2434	(1335) " . . .	Bagshot Sands and Clays. 1899.
2435	(1336) " . . .	Bagshot Sands. 1899.
2436	(1338) The Agglestone, near Studland.	" " } Indurated Mass of Strata.
2437	(1339) The Agglestone, near Studland	" " } Indurated Mass of Strata.
2438	(1340) The Agglestone, near Studland	" " } Indurated Mass of Strata.
2439	(1342) Durlston Bay, Swanage.	'The Cinder Bed,' Middle Purbeck. 1899.
2440	(1343) " " .	Anticline of Peverel Point, Upper Purbeck. 1899.
2441	(1345) " " .	Middle Purbeck between two faults. 1899.

Photographed by S. H. REYNOLDS, *University College, Bristol.* 1/2 *and* 1/4.

2442	(18) Durdle Door . . .	Arch of denudation, Portland Beds. 1899.
2443	(19) Man-of-war Cove, Lulworth	Sea-stacks of Portland Stone. 1899.
2444	(20) Stair Cove, Lulworth .	Contortions in Lower and Middle Purbeck Rocks. 1899.
2445	(21) W. side of Lulworth Cove.	Weathering and faulting of Middle Purbeck Rocks. 1899.
2446	(22) W. side of Pondfield Cove	'Broken Beds' in Lower Purbeck Rocks. 1899.
2447	(23) Bacon Hole, Mewp Bay .	Sea-stacks of Portland Stone capped by Purbeck 'Broken Beds.' 1899.
2448	(24) " "	Sea-stacks of Portland Stone capped by Purbeck 'Broken Beds.' 1899.
2449	(25) Mewp Bay . . .	Sea-stacks of Portland and Purbeck Rocks. 1899.
2450	(26) " "	" " " "
2451	(27) Bat's Corner . . .	Thrust-plane in Chalk cliffs. 1899.
2452	(28) W. of Lulworth Cove .	Resistent character of hard Portland Rocks. 1899.

Regd. No.		
2453	(29) Swire Head . . .	Thrust-plane and inversion in Chalk. 1899.
2454	(30) E. of Swire Head . .	„ „ „ „
2455	(31) Man-of-war Cove . .	Inverted Upper Cretaceous Rocks. 1899.
2456	(32) „ „	Crushed Flints. 1899.
2457	(33) Arishmell Gap . . .	Vertical bands of crushed flints. 1899.
2458	(34) Near Durdle Door . .	Masses of chert in Upper Greensand. 1899.
2459	(35) „ „	Vertical Upper Greensand with chert masses. 1899.

DURHAM.—*Photographed by* W. W. MIDGLEY, *The Museum, Bolton.* 1/2.

2336	(7) Roker Rocks, near Sunderland.	Concretionary Magnesian Limestone. 1896.

Photographed by E. J. GARWOOD, *Dryden Chambers, Oxford Street, W.C.* 12/10 E.

2502	( ) Marsden Rock, near Sunderland.	Sea-stack of Magnesian Limestone.

ESSEX.—*Photographed by* A. E. MURRAY, *St. Clare, Upper Walmer.* 1/2.

2427	(1 D) Half mile S. of Dovercourt.	Rapid advance of the sea. 1899.
2428	(2 D) „ „ „	„ „ „ „

GLOUCESTER.—*Photographed by* S. H. REYNOLDS, *University College, Bristol.* 1/2.

2460	(1) Observatory Hill, Clifton .	The Clifton Fault. 1899.
2461	(2) „ „ „	„ „ „ Junction of Millstone Grit and Carboniferous Limestone. 1899.
2462	(3) „ „ „	Detail of Clifton Fault. 1899.
2463	(4) „ „ „	Minor Thrusts in Carboniferous Limestone. 1899.
2464	(5) Observatory Hill, Clifton, and Avon Gorge.	Minor Thrusts in Carboniferous Limestone. 1899.
2465	(6) The Gully, Avon Gorge, Clifton.	Oolitic band in Carboniferous Limestone. 1899.
2466	(7) Avon Gorge, Clifton . .	The 'Gully Oolite' in the Carboniferous Limestone. 1899.
2467	(8) Hotwells and Clifton Down Road, Clifton.	Coarse Dolomitic Conglomerate. 1899.
2468	(9) Railway Cutting, near Chipping Sodbury, G.W.R.	Unconformity, Dolomitic Conglomerate on Carboniferous Limestone. 1899.

KENT.—*Photographed by* A. K. COOMARA-SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2369	( ) Charlton	Lower London Tertiaries on Chalk. 1899.
2370	( ) Erith	Drift, Thanet Sand, and Chalk. 1899.
2371	( ) Cliff near Copt Point, Folkestone.	Junction of Gault and Lower Greensand. 1899.

LANCASHIRE.—*Photographed by* W. W. MIDGLEY, *The Museum, Bolton.* 1/2.

2333	(1) Hill Pike Quarry, near Sawley.	Ferruginous Upper Mountain Limestone, folded. 1899.

Regd. No.		
2334	(2) Foxley Bank, near Grindleton.	Ferruginous Upper Mountain Limestone folded. 1899.
2335	(5) Foxley Bank, near Grindleton.	Ferruginous Upper Mountain Limestone, folded. 1899.

Photographed by G. BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/1.

2493	(5184) Pimlico Quarry, near Clitheroe.	Transverse section of Carboniferous Limestone Knoll. 1900.
2494	(5185) Pimlico Quarry, near Clitheroe.	Escarpment edge of Limestone in Knoll. 1900.
2495	(5186) Pimlico Quarry, near Clitheroe.	Slab of Carboniferous Limestone with heads and stems of crinoids from Knoll. 1900.
2496	(5186 1/2) Pimlico Quarry, near Clitheroe.	Carboniferous Limestone with slickensides. 1900.

LINCOLN.—*Photographed by* J. HOLLINGWORTH, *Holderness Road, Hull, and communicated through the Hull Geological Society.* 1/2.

477	(12) 'The Cliff,' S. of Humber, between Barton and Ferriby.	M. Chalk on L. Chalk with black marl between. 1897.
478	(13) 'The Cliff,' S. of Humber, between Barton and Ferriby.	M. Chalk on L. Chalk, with black marl between. 1897.
479	(14) South of Humber, near Ferriby 'Cliff.'	Disturbed beds of Chalk. 1897.

NORFOLK.—*Photographed by* Messrs. RALPH *and* JULYAN,* *King's Lynn, and presented by* W. T. TUCKER, *Park Side, Loughborough.* 1/1.

2497	(1543*a*) Near Railway Station, Hunstanton.	Gravel pit showing site in which human bones were found. 1897.
2498	(1543*b*) Near Railway Station, Hunstanton.	Gravel pit showing site in which human bones were found. 1897.

NORTHUMBERLAND.—*Photographer unknown.*

2503	( ) Coaley Hill, near Newcastle-on-Tyne.	Outcrop of Coal-seam.

NOTTINGHAM.—*Photographed by* J. T. RILEY, *and enlarged by* E. W. SMALL, *The Mount, Derby.* 1/1 E.

2499	(N 900) Quarry near Hucknall Torkard.	Anticline in Magnesian Limestone. 1890 ?

SHROPSHIRE.—*Photographed by* E. S. COBBOLD, *Watling House, Church Stretton.* 1/4.

2635	(3) Comley Quarry, near The Lawley, Church Stretton.	Cambrian Olenellus Limestone. 1899.
2636	(2) Sand-pit, west slope of Hazler, Church Stretton.	Sandy drift dipping steeply to N.W. 1898.
2637	(4) Lawrence Hill Quarry, Wrekin.	Banded coarse and fine Uriconian tuffs. 1899.
2638	(5) Lawrence Hill Quarry, Wrekin.	Banded coarse and fine Uriconian tuffs. 1899.

SOMERSET.—*Photographed by* S. H. REYNOLDS, *University College, Bristol.* 1/4.

Regd. No.		
2469	(13) Shore between Portishead and Clevedon.	Unconformity of Dolomitic Conglomerate on Old Red Sandstone. 1899.
2470	(11) " " "	Unconformity of Dolomitic Conglomerate on Old Red Sandstone. 1899.
2471	(12) " " "	Unconformity of Dolomitic Conglomerate on Old Red Sandstone. 1899.
2472	(13) Woodhill Bay, Portishead .	False-bedding in Old Red Sandstone. 1899.
2473	(14) Farley Down, Bath . .	Weathering of Great Oolite. 1899.
2474	(15) " "	Freestone and 'Rag' in Great Oolite. 1899.
2475	(16) " "	False-bedding in Great Oolite. 1899.
2476	(17) " "	" " "

SURREY.—*Photographed by* J. H. PLEDGE,* 115 *Richmond Road, N.E.* 1/2.

2504	(S1) Gravelly Hill, Caterham .	Clay-with-flints over flint-pebble gravel. 1899.
2505	(S3) N. of road between Bletchingley and Tilburstow Hill.	Massive cherts, &c., of the Lower Greensand. 1899.
2506	(S4) N. of road between Bletchingley and Tilburstow Hill.	Massive cherts, &c., of the Lower Greensand. 1899.
2507	(S8) N. of road between Bletchingley and Tilburstow Hill.	Chert in Lower Greensand. 1900.
2508	(S7) N.N.W. of Tilburstow Hill Farm.	High dip in Lower Greensand. 1900.
2509	(S5) S. of Oxted Station . .	Folkestone Sands in Lower Greensand. 1900.
2510	(S6) N. of Oxted village . .	Folkestone Sands in Lower Greensand, 1900.

Photographed by H. W. MONCKTON, 10 *King's Bench Walk, Temple, E.C.* 1/4.

2511	(851) Chobham Ridges, Jackpond Hill.	Sarsen in gravel. 1897.
2512	(854) Chobham Ridges, R. Albert Asylum.	Large Sarsen. 1897.
2513	(855) Chobham Ridges, R. Albert Asylum.	Sarsens. 1897.
2514	(856) Chobham Ridges, R. Albert Asylum.	Large Sarsen. 1897.

SUSSEX.—*Photographed by* F. CHAPMAN, 111 *Oakhill Road, Putney, S.W.* 1/4.

400	( ) Cliff at Aldrington, near Brighton.	Raised Beach and Rubble drift. 1899.

WESTMORELAND.—*Photographed by* LORD AVEBURY, *High Elms, Farnborough, Kent.* 1/4.

2411	( ) Near Shap	'Grikes' or widened joints in Carboniferous Limestone.
2412	( ) Loughrigg Fell, near Ambleside.	Rugged Fell made of Ordovician Volcanic Rocks.
2413	( ) Loughrigg Fell, near Ambleside.	Smooth hills of Silurian Rocks.

Regd. No.		
2414	( ) Churchyard, Ambleside	Roche moutonnée.
2415	( ) „ „	Glacial grooves in roche moutonnée.

YORKSHIRE.—*Photographed by* G. BINGLEY, *Thornichurst, Headingley, Leeds.* 1/1, 1/2 *and* 1/4.

2392	(5051) Conyngham Hall, Knaresborough.	R. Nidd flowing over highly inclined Millstone Grit. 1899.
2393	(5052) Conyngham Hall, Knaresborough.	R. Nidd flowing over highly inclined Millstone Grit. 1899.
2394	(5053) Lingerfield Quarry, Scriven, near Knaresborough.	Red Boulder-clay on Millstone Grit. 1899.
2395	(5054) Lingerfield Schoolhouse	Moraine gravels covered by red Boulder-clay. 1899.
2396	(5055) Scotton gravel pit	Moraine sands and gravels. 1899.
2397	(5056) Barf Lane, Farnham	Extra-morainic stream course, looking W. 1899.
2398	(5057) „ „	Extra-morainic stream course, looking N.E. 1899.
2399	(5058) Cayton Gill, Morcar Wood, Markington.	Intake of Cayton Gill Valley. 1899.
2400	(5059) Cayton Gill, Morcar Wood, Markington.	Looking down valley (Dole Bank). 1899.
2401	(5060) Cayton Gill, Morcar Wood, Markington.	Lateral escape of Markington Beck. 1899.
2402	(5061) Cayton Gill, Morcar Wood, Markington.	Valley looking down stream from road at Dole Bank. 1899.
2403	(5062) Cayton Gill, Morcar Wood, Markington.	Inlet of lateral stream at Shutt House, first tributary. 1899.
2404	(5063) Cayton Gill, Morcar Wood, Markington.	Fan delta of first tributary lateral stream. 1899.
2405	(5064) Cayton Gill, Morcar Wood, Markington.	Narrowest part. 1899.
2406	(5065) Near Ripley	Outlet of Cayton Gill, looking over delta. 1899.
2407	(5067) Gray Gill, Malham	Gorge in Carboniferous Limestone. 1899.
2408	(5070) Broach Scar, Malham	Weathered joints in Carboniferous Limestone. 1899.
2409	(5071) „ „	Weathered joints in Carboniferous Limestone. 1899.
2410	(5075) Site of 'Camden,' overlooking the village of Malham.	'Waterbursts.' 1899.
2486	(5160 1/2) Ingleborough	Pot-hole in Carboniferous Limestone. 1900.
2487	(5161 1/2) „	Pot-hole in Carboniferous Limestone. 1900.
2488	(5187 1/2) Long Kin East, Ingleborough.	Pot-hole in Carboniferous Limestone. 1900.
2489	(5188 1/2) Ingleborough, E. side	Swallow-hole in Carboniferous Limestone. 1900.
2490	(5189 1/2) 'Jockey Hole,' Ingleborough.	Pot-hole in Carboniferous Limestone. 1900.
2491	(5180) Bashall, near Clitheroe	Gravel-pit in Esker. 1900.
2492	(5181) „ „	Conglomerate *in situ*, in Esker. 1900.

Photographed by J. HOLLINGWORTH, *Holderness Road, Hull, and communicated through the Hull Geological Society.* 1/2.

2480	(15) Hessle	Upper Chalk overlain by recent gravel. 1897.

Regd. No.		
2481	(16) Hessle Quarry . . .	Joints, bedding and flints in Chalk. 1897.
2482	(17) Near Skidby . . .	Flint-bands in Chalk. 1897.

Photographed by H. W. Monckton, 10 *King's Bench Walk, Temple, E.C.* 1/1 E.

2483	(761) Carnelian Bay, Scarborough	Pillar of slipped Boulder-clay. 1896.
2484	(944) " " "	Slipped Boulder-clay. 1897.
2485	(1133) " " "	Slipped Boulder-clay showing flow-structure. 1899.

WALES.

Anglesey.—*Photographed by* J. Trevor Owen, *County School, Carnarvon, and presented by* E. Greenly, *Achnashean, near Bangor.* 1/2.

2522	(1) Dwlban Point, Redwharf Bay.	Sandstone 'pipes' in Carboniferous Limestone. 1899.
2523	(2) Dwlban Point, Redwharf Bay.	Sandstone 'pipes' in Carboniferous Limestone. 1899.
2524	(3) Dwlban Point, Redwharf Bay.	Connexion of sandstone pipes with the overlying sandstone. 1899.
2525	(4) Dwlban Point, Redwharf Bay.	Large sandstone 'pipe' in Carboniferous Limestone. 1899.
2526	(5) Dwlban Point, Redwharf Bay.	Deflected glacial striæ in mouth of sandstone 'pipe.' 1899.

Carnarvon.—*Photographed by* J. Wickem,* *Bangor, and presented by* E. Greenly *on behalf of the Moel Tryfaen Committee.* 1/1 *and* 1/2.

2527	(3) Moel Tryfaen Quarry . .	General position of drifts relatively to the topographic features of the district. 1898.
2528	(1) Alexandra Quarry, Moel Tryfaen.	Shelly sands and gravels resting on slate. 1898.
2529	(2) Alexandra Quarry, Moel Tryfaen.	Shelly sands and gravels resting on slate. 1898.
2530	(4) Alexandra Quarry, Moel Tryfaen.	Boulder-clay. 1898.
2531	(5) Alexandra Quarry, Moel Tryfaen.	Sandy beds below Boulder-clay. 1898.
2532	(6) Alexandra Quarry, Moel Tryfaen.	N.W. termination of Boulder-clay in sand and gravel. 1898.
2533	(7) Alexandra Quarry, Moel Tryfaen.	Terminal displacement of slates below sands and gravels. 1898.
2534	(8) Alexandra Quarry, Moel Tryfaen.	Terminal displacement of slates below sands and gravels. 1898.
2535	(9) Alexandra Quarry, Moel Tryfaen.	Terminal curvature in slate. 1898.
2536	(10) Alexandra Quarry, Moel Tryfaen.	" " " "
2537	(11) Summit of Hill, Moel Tryfaen.	Summit rocks. 1898.

Pembroke.—*Photographed by* E. W. Small, *The Mount, Derby.* 12/9, E.

2538	(P 991) Broad Haven, St. Bride's Bay.	Contorted Coal-measure strata. 1899.
2539	(P 992) Broad Haven, St. Bride's Bay.	" " " "

Regd. No.		
2540	(P 931) Marloes Sands . .	Vertical Silurian beds. 1897.
2541	(P 973) " "	Coast-erosion in inclined strata. 1897.
2542	(P 971) The Wick, Skomer Island	Dip-slope of Ordovician conglomerate; inlet of the sea along fault. 1897.
2543	(P 972) " " "	Felsitic rocks faulted against Basalt. 1897.
2544	(P 976) " " "	Sediments faulted against Basalt. 1897
2545	(P 974) 'Tom's House,' Skomer Island.	Dip-slope of Basalt, promontory of Rhyolite. 1897.
2546	(P 981) 'The Basin,' Skomer Island.	Weathering of Spheroidal Rhyolite. 1898.
2547	(P 982) The Mewstone Inlet, Skomer Island.	Marine erosion guided by the nature of the rocks. 1898
2548	(P 983) The Mewstone Inlet, Skomer Island.	Effect of dip on surface feature. 1898.

ISLE OF MAN.

Photographed by Sir Archibald Geikie, 28 *Jermyn Street, S.W.* 5/4.

2515	(1) W. end of Cromwell's Walk, Scarlet Point.	Vertical vesicular bands in Basalt. 1899.
2516	(2) W. end of Cromwell's Walk, Scarlet Point.	Gaps in lower edge of tabular Basalt now filled with agglomerate. 1899.
2517	(3) W. end of Cromwell's Walk, Scarlet Point.	Vesicular structure in tabular Basalt parallel to the lower surface. 1899.
2518	(4) W. end of Cromwell's Walk, Scarlet Point.	Steeply inclined vesicular Basalt with wrinkled surface. 1899.
2519	(5) Foreshore under Cromwell's Walk, Scarlet.	Dome-like strip of Cherty Limestone amongst coarse agglomerate. 1899.
2520	(6) Cliff, 800 yards S. of Close-ny-Chollagh Point, Scarlet.	Laminated Ash merging into confused, unstratified ash. 1899.
2521	(7) Cliff, 500 yards S. of Close-ny-Chollagh Point, Scarlet.	Coarse Breccia of vesicular Basalt passing into solid Basalt. 1899.

SCOTLAND.

Inverness.—*Photographed by* A. K. Coomara-Swamy, *Walden, Worplesdon, Guildford.* 1/4.

2372	( ) Arnisdale, Loch Hourn .	Moine Schists of Beinn Sgriol. 1899.
2373	( ) Road from Glenelg to Arnisdale.	" " " "
2374	( ) N. of Beinn Mhialairidh, near Glenelg.	Weathered Lamprophyre Dyke. 1899.
2375	( ) N. of Rudha Mor, Sandaig.	Coast erosion of Lewisian Gneiss. 1899.
2376	( ) Sandaig, near Glenelg .	Felsite Dyke in Lewisian Gneiss. 1899.
2377	( ) Half-mile S. of Sandaig Burn.	Actinolite in Lewisian Gneiss. 1899.
2378	( ) W. of Port Luinge, near Sandaig.	Contorted Lewisian Gneiss. 1899.
2379	( ) E. of Camas-nan-geann, W. of Raisaidh, Loch Hourn.	" " " "
2380	( ) E. of Ghlas Eilean, W. of Raisaidh.	Basaltic Dyke with vesicular centre. 1899.
2381	( ) E. of Ghlas Eilean, W. of Raisaidh.	" " " "
2382	( ) Scuir-na-Gillean, from Druim-an-Eidhne, Skye.	Gabbro and Granophyre. 1899.
2383	( ) Bhasteir Tooth, Scuir-na-Gillean, Skye.	Gabbro with Basic Dykes and Sills. 1899.
2384	( ) Druim-an-Eidhne, Cuchullin Hills, Skye.	Gabbro, with fine Felsite veins. 1899.

Regd. No.		
2385	( ) Bruach-na-Frithe, Skye.	Gabbro. 1899.
2386	( ) Marsco, from Druim-an-Eidhne.	Granophyre Hills. 1899.
2387	( ) Marsco, from Glen Sligachan.	Granophyre Hill. 1899.
2388	( ) Ruadh Stac, Skye . .	Granophyre. 1899.
2389	( ) Beinn - na - Cailleach, Broadford.	Granophyre of the Red Hills. 1899.
2390	( ) Scorr, Portree Bay . .	Weathering of Basalt. 1899.
2391	( ) W. Coast of Eigg, W. of Beinn Tighe.	Sill in bedded Basalt. 1899.

Photographed by A. S. Reid, *Trinity College, Glenalmond, Perth.* 1/2 *and* 1/4.

2549	(SR 50) East Cliff of Eigg .	Basalt flows with paler Andesitic band intercalated. 1899.
2550	(SR 51) ,, ,, ,,	Basalt flows with paler Andesitic band intercalated, overlying Jurassic rocks. 1899.
2551	(SR 92) Scuir of Eigg . .	With cloud-banner. 1899.
2552	(SR 45) ,, ,,	Relation to Basalt platform. 1899.
2553	(SR 44) East end of Scuir of Eigg from N.W.	Position of E. of Scuir with regard to the Basalt platform. 1899.
2554	(KL 28) Scuir of Eigg . .	Exposure of Conglomerate under the Scuir. 1899.
2555	(KL 30) ,, ,,	Conglomerate on floor of 'Sheep Cave.' 1899.
2556	(KL 32) ,, ,,	,, ,, ,, ,,
2557	(KL 33) ,, ,,	,, ,, ,, ,,
2558	(SR 62) ,, ,,	East end of Scuir.
2559	(SR 80) East end of Scuir of Eigg from S.	Devitrified bands of Pitchstone and two exposures of the river-conglomerate. 1899.
2560	(KL 34) Scuir of Eigg . .	Devitrified band in the Pitchstone. 1899.
2561	(SR 82) ,, ,,	Devitrified and Spherulitic bands in the Pitchstone. 1899.
2562	(SR 79) East end of Scuir of Eigg.	Banding, &c., of Pitchstone. 1899.
2563	(SR 87) North-west end of Scuir of Eigg.	Truncated end of Scuir. 1899.
2564	(SR 66) Scuir of Eigg, Cornbheinne Hill.	Curvi-columnar structure of the Pitchstone. 1899.
2565	(SR 52) Laig Bay, I. of Eigg .	Erosion of dyke and its margin of fibrous Calcite. 1899.

Photographed by H. R. Blanford, 72 *Bedford Gardens, Campden Hill, W.* 1/4.

2566	(1) North end of Loch Lochy	Erosion of hills by glacial and stream erosion.
2567	(2) North end of Loch Lochy	Erosion of hills by glacial and stream erosion.
2568	(3) Hillside S.E. of Ceann Loch, Loch Lochy.	Glacial and stream erosion. 1899.
2569	(4) Hills S.E. of Laggan, between Loch Lochy and Loch Oich.	,, ,, ,, ,,
2570	(5) Hills W. of Laggan . .	,, ,, ,, ,,

IRELAND.

Antrim.—*Photographed by* W. Gray, *Glenburn Park, Belfast.* 1/2.

2339	(36*a*) White Rocks, nr. Portrush.	Marine denudation of Chalk. 1895.
2340	(44) ,, ,, ,,	Arch in Chalk. 1895.

Regd. No.		
2341	(45) Near Dunluce . . .	Chalk arch and headland capped by Basalt. 1895.
2342	(52) Giant's Causeway, Lord Antrim's Parlour.	Columnar Basalt. 1897.
2343	(53) Giant's Organ, Giant's Causeway.	Columnar Basalt with cross joints 1897.
2344	(55) Windy Gap . . .	Spheroidal weathering of Basalt. 1895.
2345	(56) Giant's Causeway . .	Iron-ore zone. 1895.
2346	(43) Ballycastle . . .	Denudation of Chalk cliffs. 1894.
2347	(42) "	" " " "
2348	(58) Larry Bane Bay, Ballycastle.	Chalk cliffs. 1894.
2349	(54) Fair Head	Denudation of Columnar Basalt. 1890.
2350	(51) Ballygally, 'Wren's Egg' .	Erratic of Basalt. 1895.
2351	(47) Whitehead	Basalt Dyke in New Red Sandstone. 1895.
2352	(46) Macedon Point. . . .	Two intersecting dykes of Basalt. 1898.

ANTRIM.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast.* 1/1.

2601	(1176) Stack-a-boy, Rathlin Is.	Sea-stack of rudely Columnar Basalt Lavas. 1899.
2602	(496) Straidkilly, Coast Road .	Village, on Lias which is continually slipping seaward. 1886.
2603	(250) Giant's Chimney Tops and Amphitheatre, Giant's Causeway.	Columnar and massive Basalt flows. 1886.
2604	(971) Giant's Causeway . .	Floor of Columnar Basalt. 1890.
2605	(976) Giant's Causeway, Middle Causeway.	Columnar Basalt. 1890.
2606	(242) Giant's Causeway, The Loom.	Long columns of Basalt. 1886.
2607	(5165) Giant's Causeway . .	Spheroidal weathering of Basalt. 1897.
2608	(978) Giant's Causeway, Portcoon Cave.	Cave worn by marine action in Spheroidal Basalt. 1886.
2609	(799) Giant's Causeway, The Stookans.	Breakers rolling over ledges of Columnar Basalt. 1887.
2610	(5775) Carey River Head . .	Lower end of underground channel draining Lough-a-veena into Carey River. 1898.
2611	(239) Carrick-a-Rede Ravine .	Sea gully in a volcanic neck. 1890.
2612	(655) Whitepark Bay, Ballintoy.	Prehistoric settlement and middens. 1897.
2613	(609) Fair Head . . .	Coarsely Columnar sheet of Dolerite. 1890.
2614	(5153) Cliffs of Murlough Bay .	Chalk cliff with talus, slipping over Trias beds below. 1898.
2615	(586) Cushendun . . .	Cave worn by marine action in coarse conglomerate of Old Red Sandstone age. 1889.
2616	(551) Ess-na-larach, Glenariff .	Ravine in Basalt worn by waterfall. 1894.
2617	(5204) Grant's Mines, Toome .	Diatomaceous Earth ('Bann clay'). 1899.

CLARE.—*Photographed by* G. FOGERTY, 61 *George's Street, Limerick.* 1/2.

2353	(3) Fanore, near Black Head .	Jointing in Carboniferous Limestone. 1899.
2354	(5) Caher, Lower, near Black Head.	Terraces of Carboniferous Limestone. 1899.
2355	(6) Black Head . . .	Escarpment Cliff of Carboniferous Limestone. 1899.
2356	(2) Farrihy Bay . . .	Marine denudation of Lower Coal-measures. 1895.
2357	(4) Cliffs of Moher . . .	Steep and lofty cliffs of Carboniferous Rocks. 1899.

DONEGAL.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast, and sent through the Belfast Naturalists' Field Club.* 1/1.

Regd. No.		
2618	(2242) Cratlagh Wood, Mulroy Bay.	Schistose area of Donegal. 1893.
2619	(2259) Rosapenna . . .	Section through sand-dune on which old kitchen-midden rests. 1893.
2620	(5209) Barnesmore Gap . .	Pass in granite area. 1900.
2621	(1440) Croaghconnellagh, Mt. Barnesmore.	Granite Mountain, cliffs over talus. 1900.
2622	(5135) The Pullins River, Ballintra.	River entering underground channel. 1894.

DOWN.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast, and sent through the Belfast Naturalists' Field Club.* 1/1.

2623	(5208) Sampson's Stone, Downpatrick.	Large Basalt erratic. 1900.
2624	(5180) Newcastle . . .	Sand-dune, showing the retaining action of Bent, &c. 1898.
2625	(5179) ,, . . .	Section of sand-dune, showing wind erosion and false-bedding. 1898.
2626	(5178) Newcastle and Slieve Donard.	Storm ridges of raised beach partly covered with sand-dunes. 1898.
2627	(5177) Newcastle . . .	Thin-bedded Ordovician strata. 1898.
2628	(5176) Cliffs at Maggie's Leap, Newcastle.	Thin-bedded, slightly contorted, Ordovician strata. 1898.

Photographed by W. GRAY, *Glenburn Park, Belfast.* 1/4.

2358	(49) Ards Coast, Strangford Lough.	Erratic Block. 1896.
2359	(50) Ballyhalbert . . .	,, on Silurian Rocks. 1896.
2360	(62) Wallace's Rocks, Ballyhalbert Road.	Folded Silurian Strata. 1895.
2361	(65) Ballyhalbert . . .	Basalt dykes in Lower Silurian Rocks. 1895.
2362	(63) Gunn's Island . . .	Basalt dykes in Lower Silurian Rocks. 1895.
2363	(61) Sheepland Harbour . .	Basalt dykes in Lower Silurian Rocks. 1895.

Photographed by Miss MARY K. ANDREWS, 12 *College Gardens, Belfast.* 1/4.

2366	(11) Newcastle, little N. of Harbour.	Erosion of sea coast. 1899.
2367	(9) Newcastle, little N. of Harbour.	,, ,,
2368	(10) Newcastle, little N. of Harbour.	,, ,,

GALWAY.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast, and sent through the Belfast Naturalists' Field Club.* 1/1.

2629	(5221) Near Ahascragh, Ballinasloe.	General character of the central Limestone Plain of Ireland. 1900.

KERRY.—*Photographed by* S. H. REYNOLDS, *University College, Bristol.* 1/4.

2585	(36) Near Clogh, Clogher Head District.	Dip of Silurian flags. 1899.

Regd. No.		
2586	(37) Gully near Clogh Point, Clogher Head District.	Influence of dip on form of gully. 1899.
2587	(39) North of Clogh Point, Clogher Head District.	Inlet eroded along junction of flags with overlying tuffs. 1899.
2588	(40) North of Drom Point, Clogher Head District.	Bedded tuffs alternating with Sandstone bands. 1899.
2589	(41) North of Drom Point, Clogher Head District.	Alternating coarse and fine tuffs and Red Sandstone. 1899.
2590	(38) Inlet S.E. of Foilwee, Clogher Head District.	Erosion along bedding plane. 1899.
2591	(42) S. of Foilwee, Clogher Head District.	Faulting in bedded tuffs. 1899.
2592	(43) Coosmore, Clogher Head District.	Disturbed Ludlow beds. 1899.
2593	(44) Doon Point and Sybil Head, Clogher Head District.	Joint cave. 1899.
2594	(45) Minnaunmore Rock and Croaghmarhin Hill.	Rugged rhyolite hill and smooth hill of Silurian slate. 1899.
2595	(46) Clogher Head District .	'Fucoid markings' on Ludlow flags. 1899.
2596	(47) North side of Clogher Head.	Rhyolite blocks in coarse ash. 1899.
2597	(48) South-east of Foilwee, Clogher Head District.	Weathered surface of nodular rhyolite. 1899.
2598	(49) Minnaunmore Rock, Clogher Head District.	Weathered surface of nodular rhyolite. 1899.
2599	(50) West of Redcliffe Cove, Clogher Head District.	Weathered surface of tuff. 1899.
2600	(51) Off Bull's Head, Dingle Promontory.	Sea-stack of Dingle beds. 1899.

LIMERICK.—*Photographed by* G. FOGERTY, 61 *George's Street, Limerick.* 1/2.

2365	(1) Caherconlish . . .	Columnar porphyritic igneous rock. 1897

LONDONDERRY.—*Photographed by* W. GRAY, *Glenburn Park, Belfast.* 1/2.

2364	(66) Benbradagh . . .	Chalk quarry, the most westerly in Europe. 1899.

MEATH.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast, and sent through the Belfast Naturalists' Field Club.* 1/1.

2630	(1150) Gorge of the Boyne at Beauparc.	Contorted Carboniferous Limestone cut through by river. 1900.
2631	(5222) Gorge of the Boyne at Beauparc.	Contorted Carboniferous Limestone cut through by river: near view. 1900.

SLIGO.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast, and sent through the Belfast Naturalists' Field Club.* 1/1.

2632	(2095) Glencar, Sligo . .	Escarpment cliff of Carboniferous Limestone. 1892.
2633	(2100) Glencar Fall, near Sligo .	Cirque with waterfall in Carboniferous Limestone. 1892.

ROCK-STRUCTURES, &c.

Photographed by W. W. MIDGLEY, *The Museum, Bolton.* 1/4.

2337	(4) Castleton, Derbyshire . .	Coralline Mountain Limestone (micro.).
2338	(5) Corriegills, Arran . .	Pitchstone (micro.).

Regd. No.		
2572	(8) Ennerdale, Cumberland .	Granophyre. ×20.
2573	(9) Luxulyan, Cornwall . .	Schorl-granite. ×20.
2574	(11) Tormore Shore, Arran .	Pitchstone. ×60.
2575	(12) Brodick School House, Arran.	Pitchstone. ×60.
2576	(14) Arran	Spherulites. ×20.
2577	(16) Bolton, Lancashire . .	Blast-furnace slag. ×20.
2578	(17) Giant's Causeway, Antrim .	Basalt. ×20.
2579	(18) River Coquet, Rothbury, Northumberland.	Dolerite. ×20.
2580	(23) Cloughwater, Antrim .	Rhyolite, with flow-structure. ×20.
2581	(26) Keswick, Cumberland .	Agates in volcanic ash. ×20.
2582	(29) Inchcolm Rock . . .	Picrite. ×20.
2583	(30) Near Edinburgh . .	Picrite. ×20.
2584	(36) Wolf Rock, Cornwall .	Phonolite. ×20.

Photographed by G. BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/4.

2571 (5190) Salthill Quarry, Clitheroe *Spirifera striata*, showing spiral arms. 1900.

LIST II.

NUMBERS OF OLD PHOTOGRAPHS CANCELLED.

191, 399, 400.

LIST III.

RENEWALS AND CORRECTIONS.

Renewals.

YORKSHIRE.—*Renewed by* G. BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

506 (1755) How Stean Beck, Upper Nidderdale, near Pateley Bridge. Deep Gorge in Carboniferous Limestone. 1891.

DEVON.—*Renewed by* A. K. COOMARA-SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2058 ( ) Bindon, W. of Lyme Regis. Cliff caused by Landslip. 1898.

ANTRIM.—*Renewed by* J. BROWN, *Belair, Windsor Avenue, Belfast.* 1/2.

657 ( ) Muck Island . . . . Marine Denudation. 1892.

DOWN.—*Renewed by* Miss M. K. ANDREWS, 12 *College Gardens, Belfast.* 1/2.

340 ( ) Copeland Island . . . Lower Silurian Rocks. 1891.

LONDONDERRY.—*Renewed by* Miss M. K. ANDREWS, 12 *College Gardens, Belfast.* 1/2.

529 ( ) Downhill . . . . . Chalk underlying basalt. 1891.

Corrections.

WORCESTERSHIRE.—*Photographed by* W. J. HARRISON, 52 *Claremont Road, Handsworth, Birmingham.* 1/2.

1440 ( ) California, near Birmingham Boulder clay. 1896.
1441 ( ) „ „ „ 'Indiarubber clay' on Till. 1896.

Regd. No.		
1442	( ) Moseley, near Birmingham .	Glacial sands. 1896.
2275	( ) California, near Birmingham	Bunter Sandstone.

LIST IV.

THE DUPLICATE (LOAN) COLLECTION.

The numbers placed after the description of the photograph refer to the list of names and addresses given at the end. The first refers to the photographer, who is also the donor in most cases. When he is not, the donor is indicated by a second number.

Full localities and descriptions are given in present and previous lists under the numbers.

This collection is arranged geologically, and from time to time the less perfect and less typical photographs will be removed and better ones substituted as they are given. Those laid aside can always be seen, sent, or returned by request.

* Indicates that prints and slides may be bought from the photographer. P. indicates prints. S. indicates slides.

Rock-Structures.

Bedding.

Regd. No.		
1664	Bedding and Jointing in Carboniferous Limestone.	Muckros 'Market House,' Kilcar, Donegal. 9 P.*

Evidences of Earth-movement.

Elevation and Subsidence.

1887	Raised Beach on Pilton Beds .	Saunton Down End, Barnstaple Bay. 49 S.

Folding.

2425	Anticline in Culm-measures .	Cockington Beach, near Bideford. 40 P.S.
2426	Anticline in Culm-measures .	Cockington Beach, near Bideford. 40 P.
40	Folded Carboniferous Limestone	Draughton, near Skipton. 21 S. 15.
2378	Contorted Lewisian Gneiss .	West of Port Luinge, near Sandaig, Glenelg. 40 P.S.

Surface Agencies; Denudation and Deposit.

Weathering.

2270	Honeycomb-weathering in Keuper Sandstone.	Budleigh Salterton. 49 S.
2437	Outstanding Rock	The Agglestone, near Studland, Dorset. 59 S.
2438	" "	" " "

Volcanic and Plutonic Rocks.

Volcanoes.

F. 26	Crater Lake	Pulvermaar, Eifel, Germany. 40 P.

Rock-masses and their Relations.

Regd. No.		
F. **11**	Alternations of Basalt lava and tuff.	'Cascade Section,' Mont Dore, Auvergne, France. 40 S.
2374	Weathered-out Lamprophyre dyke.	North of Beinn Mhialairidh, near Glenelg. 40 S.

Characteristic Rocks and Landscapes.

Palæozoic.

2377	Actinolite in Lewisian Gneiss .	Half a mile south of Sandaig Burn, near Glenelg. 40 S.
138	Coal-measures above Beeston Bed.	Longley's Brickyard, Leeds. 58 P.
139	Coal-measures including Beeston Bed Coal	Grosvenor Brickyard, Leeds. 58 P.
140	Coal-measures above the Crow Coal.	Boyle's Quarry, Leeds. 58 P.
141	Coal-measures including Crow Coal.	" " "
142	'Black Bed' Coal Seam . .	Dolly Lane Brickyard, Leeds. 58 P.
143	'Better Bed' Coal Seam . .	Benson Street Brickyard, Leeds. 58 P.

Mesozoic.

990	Paramoudras in Chalk . .	Soldierstown, Moira, Antrim. 56 P.

Names and Addresses of Donors and Photographers.

9. R. Welch, Lonsdale Street, Belfast.
15. A. S. Reid, Trinity College, Glenalmond, Perth.
21. Professor E. Waymouth Reid, University College, Dundee.
40. A. K. Coomara-Swamy, Walden, Worplesdon, Guildford.
49. Miss E. M. Partridge, 75 High Street, Barnstaple.
56. W. Gray, Glenburn Park, Belfast.
58. F. W. Branson, 14 Commercial Street, Leeds.
59. H. W. Monckton, 10 King's Bench Walk, Temple, E.C.

On the Geological Age of the Earth. By Professor J. Joly, *D.Sc., F.R.S.*

[Ordered by the General Committee to be printed *in extenso.*]

On account of a certain small amount of arithmetical complexity involved in the statement of the method of estimating the age of the earth by solvent denudation, I have had a brief summary of it put into print, all the quantities involved being calculated into the metrical system of units (see Appendix). With this in your hands I may be permitted to leave figures aside in the few remarks I have to make.

In this *method*, as the President of the Geological Section has already stated, the sodium contained in the sea is assumed to be a measure of the total amount of solvent denudation since the oceans were formed, and the amount of sodium annually supplied by the rivers is taken as a measure of the rate at which this denudation has been effected. Why attention is *restricted to the sodium* need not be enlarged upon further than to say that every other element supplied by solution of the rocks is again rejected by the sea to an extent which renders it unavailable.

It will be found on reference to the summary that allowance is made for the effects of the probable amount of *active acid primevally uncom-*

bined, on the basis that sensibly the whole of the chlorine now in the ocean was then existent in the form of HCl. This amounts to a subtractive correction of under 6 per cent. on geological time. After consideration of all the facts, I do not think any further concession to the popular assertion, that 'the sea was salt from the first,' can be made.

A deduction is also suggested for direct *solvent denudation by the sea.* The correction is taken as between 3 and 6 per cent., the basis of correction being the ratio of the tide-swept area to the total rainy land area, and some experiments which appear to show that over the same area of rock surface the rate of marine solution cannot be more than twenty times the rate of atmospheric denudation These experiments are communicated to this Section. They are somewhat incomplete, but their rough indication may be accepted as sufficient for the present purpose.

Allowance is also made for the *transport of sodium from the sea to the rivers* through the atmosphere. Data are required in order to define this allowance more precisely.

The brief review of the method before you also refers to the *rock-salt deposits.* These appear to be quite negligible compared with the enormous mass of chloride of sodium now in the ocean—sufficient to cover the entire land area to a depth of 122 metres—unless deposits of this substance, far greater than anything at present dreamt of, are discovered.

Some other possible sources of error are considered, but these will more fitly be referred to further on.

It is a *confirmation of the general validity* of the method that accepting—with slight modifications—Mr. Mellard Reade's estimate of the total mass of detrital sediments, and a mean soda content of these sediments, based on a very considerable number of analyses, we find that the resulting total mass of contained sodium added to the soda equivalent of the sodium now in the ocean suffices to restore to the adequate mass of parent igneous rock a soda percentage approximately equal to that of the mean igneous crust-rock of the earth. In other words what sodium is contained in the ocean is approximately equal to the amount which would have been wasted from such a mean igneous rock upon its degradation into the probable mass of detrital sediments.

Finally we find the method affords on the basis of the best data available a duration since subaërial denudation began of *between ninety and one hundred millions of years.*

Professor Sollas has really referred to the *weakest point in this estimate* when he questions the sufficiency of the data affording the annual river supply of sodium. However, there is much reason to believe that the nineteen rivers—a fair admixture of great and small ones—afford an approximation to the nature of what the world's rivers yield in the form of dissolved matter to the ocean. The want emphasises Professor Sollas's demand for more experiment, and Sir Archibald Geikie's for geological co-operation. The data required are really of the easiest to obtain.

The method is, of course, based on the principle of uniformity, but the *generalised nature of the measure of uniformity* actually required is worthy of attention. The claim is restricted to the *association of atmospheric water and of rock* over a surface of land approximately equal to the present rainy area of the globe, the climatic conditions doubtless differing in each geographical region from age to age, but on the whole preserving an approximate uniformity in denudative effect, as measured, say, by the solvent denudative work accomplished per million of years.

How far will this measure of uniformity be conceded? *Whether crystalline or sedimentary rocks prevail* does not appear seriously involved in the long run, for we find soils derived from the latter actually exposing larger amounts of alkaline silicates: the higher resistance to disintegration offered by the crystalline rocks often conferring upon their soils the rôle of an exhausted and protective covering. Again, it is only within fairly wide limits *a question of climate*, for the rate of solution of the silicates is so slow that the amount of the solvent present is of less importance than its persistent operation even in minute quantities. The rate of solution would certainly not increase proportionately to the amount of the solvent, a very wet climate being very possibly, even probably, less effective than a warm and damp climate more rarely visited by rains.

As regards the *rainy area exposed to subaërial denudation* during past geological periods, considerable latitude with respect to the effects of upheaval or depression is suggested by the fact that the supply of water evaporated by the ocean is to-day insufficient to ensure drainage from more than four-fifths the total land area. If to-day 10 per cent. of the land subsided beneath the ocean, probably but a small change in the river discharge of dissolved matter would result. The disappearance of this 10 per cent. of the land would increase the oceanic area but 4 per cent., and the 'rainless' areas of the continents would diminish to one-tenth the total land surface. In short, the rainy margins would—roughly speaking—move inwards. In the opposite case, that of upheaval, the rainy margin will move outwards. Thus the deposition or upheaval of our greatest sedimentary masses was not necessarily accompanied by any notable variation in the supply of dissolved matter to the sea.

In short, it would appear that *changes of a quite abnormal or catastrophic nature* must be looked for to seriously affect the average rate of the operations at work. I must refer to the evidence for and against such effects.

As regards *hydrothermal actions*, due to lingering heat in the primitive oceans, on Lord Kelvin's figures for the rate of cooling this action must be negligible. If his figures were multiplied even tenfold, the error could hardly at most amount to 1 per cent. I may also now refer to the objection urged by Professor Sollas, that underground temperature may for long have given rise to a geyser-like action of springs which would have enriched the sodium supply of the early rivers. If of a serious character this objection should be supported by more evidence of such solvent actions than our most ancient sediments reveal. Thus it is remarkable that so far from the earliest sediments or their probable metamorphosed remains being the most washed-out of the rocks they are often those possessing the largest percentages of alkalies. The oldest Cambrian and Silurian sediments and gneissic rocks of archæan age and probable sedimentary origin show percentages of alkalies almost comparable to those of the mean igneous earth-crust and exceeding the average of later sediments and of sediments at present being deposited. I therefore cannot think that any exceptional solvent actions applied to these sediments when being deposited or when buried or subsequently when uplifted and exposed to atmospheric denudation can be generally assumed. Geyser actions or circulation of underground waters among unfaulted primitive igneous rocks, on the other hand, would arise only under exceptional conditions. And, again, we may ask, where in the earlier igneous rock-masses have we evidence of exceptional geyser-like actions?

I may point out here that Daubrée's experiments by no means support the view that crystalline rocks are rapidly attacked by superheated water, but rather demonstrate the contrary. At a pressure which Daubrée estimated at more than 1,000 atmospheres, and at a red heat, water failed to appreciably attack, after many weeks, sanidine, oligoclase, pyroxene, or potash mica. The contrary is generally inferred from the general attention which has been paid to his experiments on glass and obsidian. The early igneous rock crust from the general prevalence of conditions of slow cooling would almost certainly have been highly crystalline.

The notion that *exceptional vulcanism* prevailed in the earliest times appears unproved. The traps and dykes of archæan rocks are not always evidence of subaërial outbursts—the Lewisian and Torridonian rocks of Scotland may be quoted as examples, where, although there is much injection of igneous matter, there is no evidence of corresponding volcanic action. And, again, it may be well questioned, granting even excessive volcanic action, how far it would affect the methodical supply to the ocean of dissolved alkalies by the rivers.

Early tides of gigantic height have been rather discredited. Any one reading Professor G. Darwin's delightful book on 'Tides' will be struck with the caution and moderation of the writer. He maintains 'the possibility that a considerable part of the changes due to tidal friction may have occurred within geological history,' yet thinks it 'probable that the greater part of the changes due to tidal friction must be referred back to pre-geological times when the planet was partially or entirely molten.' This involves, of course, that the epoch of most violent activity prevailed in pre-geological times before the work of denudation had begun. And here, again, even admitting higher tides, it may be seriously asked on what grounds we assume such higher tides to effect solvent denudation positively rather than negatively. If the tides of to-day rose so as to encroach five miles further on the coasts, would the loss of soil area resulting compensate for the gain of bare superficial rock swept by the sea? A soil but 10 cms. deep may expose an area 50,000 times its superficial area to the solvent actions of hygroscopic water and rain, CO_2, organic acids, &c.

Professor Perry, writing in 'Nature,' has suggested the possibility of *diminished sun-heat* at a period as recent as some 50×10^6 years ago. But so far as I know, Professor Perry has not gone further than to suggest the possibility of this external interference with the orderly succession of events in the earth.

But finally in regard to all these surmises, interesting and valuable as they undoubtedly are, can I do better than to refer to Sir A. Geikie's reading of *rock-testimony* on this point? Sir A. Geikie seeks one hundred million years as sufficient for the sedimentary history of the earth. His words are recent—dating from his address to the Geological Section last year. The evidence of the sedimentary rocks, he affirms, shows no more stupendous mountain upheavals, volcanic eruptions, or greater violence in the surrounding envelopes of atmosphere and ocean than occurred in more recent periods or than we are acquainted with to-day. 'Even in the most ancient of the sedimentary registers of the world's history not only is there no evidence of colossal floods, tides, and denudation, but there is incontestable proof of continuous orderly deposition such as may be witnessed to-day in any quarter of the globe. The same tale with endless additional detail is told all through the stratified formations down to those which are in course of accumulation at the present day.'

If now the sodium-method affords a correct key to the age of the earth, it remains to *criticise methods yielding discordant results.* And first, as regards the *method by rate of deposition,* we find Sir A. Geikie claiming a period, as we have seen, in perfect accord with that shown by solvent denudation. Professor Sollas, however, considers the actual record indicates a shorter period. I think, however, he has very fully and fairly shown that much difficulty attends the actual measurements as well as the application of the measurements.

In the first place it may be observed that the data have been obtained from an inadequate number of rivers. Again, the detrital matter discharged by rivers is most difficult to estimate, owing to the rapid variation of transporting power with current-velocity, and also owing to the fact that a very large amount of sediment is transported by creeping along the river bed. Both these facts render measurement so difficult that only the most painstaking observations could be relied on for an approximate estimate. And suppose we possessed the required estimate of detrital material, how are we to dispose of it so as to represent what we may call the average mode of maximum deposition? Some rivers form deltas which creep outward year by year. Here the rate of deposition is evidently not balanced by subsidence. There is in fact no one law of deposition, nor can there be. Once more, can we ever know the total maximum thickness of the sediments? It must be that the sediments of one period supply in great part those of the next. The very quantity we estimate in the rivers in order to find our denominator has been robbed, perchance, from our numerator. Have we, in fact, when all care is taken, measured the true maximum thickness, or would sediments long ago removed afford vastly greater maxima? Now observe the method is exposed, here at its weakest point, mainly to errors of deficiency: and the method in its latest development, in the able hands of Professor Sollas, affords but some twenty-six millions of years, and according to Mr. Wallace twenty-eight millions of years.

There is another method based on *biological progress* which seems to go to the opposite extreme and claims immense periods of time. Lyell claimed on biological grounds 240 millions of years since the Cambrian; Haughton, 200 millions; Darwin speaks of a pre-Cambrian period as long as the sum of the subsequent geological ages. Professor Sollas has, with justifiable authority, dealt with this matter. And indeed we may well ask if the argument does not assume an unwarranted proportionality in the rates of evolution throughout successive ages. Surely the organism of later date owes something of its stability to heredity?

Can we assume that when trial was less likely to be attended with error, owing to a less severe competition, species and genera were not struck off more rapidly than later under more restricted conditions, and when ages of increasing restraints had impressed upon the germ-plasm a more stereotyped heredity? It appears difficult to imagine that the organism as we see it to-day so willing to take advantage of every loophole and fill up every vacancy should have dropped its opportunist character in early times and failed to profit by the more generous environment. If this is so, can we accept with Huxley the period required for the development of the horse as an indication of the length of the history of ungulates? But this argument has been taken up already by Mr. Adam Sedgwick, who has urged that in the evolution

of heredity a reconciliation of the demands of biologists and the restrictions placed by the physicist on geological time may be found. His address to the Zoological Section last year will be fresh in the minds of all, and I need not further press the point.

Turning to physical methods we have Professor Darwin's *age of the moon*, suggesting a minimum of fifty-seven millions of years, to which Professor Sollas has referred. *Lord Kelvin's method*, based on the rate of cooling of the globe and the observed fall of temperature in the terrestrial crust, depends for the accuracy of its indication on data regarding the physical properties of the deeper-lying materials of the earth which we do not as yet possess. This has been fully discussed lately by Professor Perry. The distinguished author of the method has at no time denied the restrictions placed by our present ignorance on the indications of the method. The effect is not to deprive the method of value, but to restrict its present functions to the delimitation of certain bounds to our speculations, which bounds may on the minor estimate be taken as some twenty millions of years, but which may, according to the density, specific heat, and conductivity of the deeper-lying materials at elevated temperatures, allow of a much more extended estimate.

It must be admitted that no one method of approaching the delicate question of the age of the earth can claim to have reached that *consistentior status* which we look for in scientific results. So much may possibly have happened during the long past vista which it is hoped to penetrate that more than a considerable degree of probability may never be attained by our results. Admitting this, I have to appear perhaps in the light of an advocate when I state my belief that the method by solvent denudation is not discredited by the conclusions arrived at by other methods, in so far as these assign major or minor limits to the age of the earth, and that none other approaches the question so directly or on such easily obtained data.

APPENDIX.

The Geological Age of the Earth.

[Read before the Congrès Géologique International, 1900.]

The method of determining the age of the earth summarised in this paper is based on the assumption that the ocean has retained substantially the whole of the sodium committed to it by the solvent denudation of geological time, and that the supply of the element sodium by the rivers has on the whole been uniform in rate.[1]

Hence we derive as a numerator a number expressing the mass of sodium at present in the ocean, and a denominator expressing in the same units the amount of this element annually discharged into the ocean by the rivers of the world.

The quotient is the geological age of the earth.

Corrections are applied to both numerator and denominator for any certain or very probable source of error. These corrections are approximate only, upper and lower limits of their values being suggested.[2]

[1] No other dissolved substance in the ocean conforms to the first of these conditions.

[2] A more amplified account of what follows will be found in a paper by the author, 'An Estimate of the Geological Age of the Earth,' *Trans. Royal Dublin*

First Approximation to a Numerator.

According to Professor Dittmar,[1] if the ocean has a total mass of $1 \cdot 343 \times 10^{18}$ tonnes, the sodium chloride in it amounts to $36{,}566 \times 10^{12}$ tonnes. However, on Professor Wagner's[2] estimate of the area of the land surface of the globe as $14{,}456 \times 10^4$ square kilometres, and the ratio of the areas of water and land as $2 \cdot 54 : 1$, and on Sir John Murray's estimate[3] of the mean depth as 3·851 kilometres, the total mass is more correctly $1 \cdot 458 \times 10^{18}$ tonnes. On these data we can readjust Professor Dittmar's estimate of the mass of NaCl in the ocean, finding it to be $39{,}703 \times 10^{12}$ tonnes, and from this finally arrive at the result that the mass of sodium in the ocean is $15{,}611 \times 10^{12}$ tonnes.

First Approximation to a Denominator.

On Sir John Murray's estimate[4] the river water annually discharged into the ocean amounts to a volume of 27,191 cubic kilometres, and from his table of the mean dissolved constituents of nineteen rivers—many of them principal rivers of the world—we find that a cubic kilometre of average river water contains as sodium salts 7753 tonnes of Na_2SO_4, 6534 tonnes of $NaNO_3$, and 4061 tonnes of NaCl. Calculating from these the masses of sodium in each case, and multiplying by the total number of cubic kilometres, we arrive at $15{,}976 \times 10^4$ tonnes as the total mass of sodium carried annually into the sea by the rivers.

The quotient is a first approximation to the age of the earth, and is 97·6 millions of years.

Correction on the Denominator.

It is convenient to consider this first.

The mass of sodium chloride carried by the rivers is in part derived from the ocean by means of the atmospheric transportation of this substance from the ocean and its precipitation in rain water. Ten per cent. is allowed as a sufficient deduction for this circulation of the chloride of sodium. The allowance is thus restricted for the reason that while near the coasts a very considerable portion, and even sensibly the whole, of the chloride of sodium may be so derived, in inland areas the amounts of the salt which fall in rain become very minute.[5] It is just in these inland areas that the chief rivers of the world derive their supplies.

Applying this correction to the NaCl of the rivers, the corrected river discharge of sodium is left at $15{,}542 \times 10^4$ tonnes.

Corrections on the Numerator.

(a) *For the Original State of the Ocean.*—We assume that the sodium as well as most of the metals was silicated in the original crust of the earth. The chlorine, with great probability, was gaseous and combined

Society, vol. vii. (ser. ii.), 1899, p. 23 *et seq.* See also *Geological Magazine*, 4, 1900, vol. vii. *et seq.*

[1] 'Challenger' Report, *Physics and Chemistry*, vol. i.

[2] *Scottish Geographical Magazine*, 1895, p. 185. The measurements throughout have been converted from the British system of units.

[3] *Loc. cit.*, 1888, p. 1 *et seq.*

[4] *Loc. cit.*, 1887, p. 76.

[5] On the west and east coasts of Scotland 1·19 and 1·26 per 100,000 respectively. In Swiss valleys 0·25 to 0·76 per 100,000, and in Ootacamund, India, 0·04 per 100,000.

with hydrogen. The resulting acid we assume as probably contained in the original atmosphere and hydrosphere. A primitive accelerated denudation can be computed on the basis of the probable mass of chloride of hydrogen and the nature of the lithosphere exposed to attack. The effects concern the present method only so far as they result in supplying sodium to the ocean.

The maximum amount of chlorine available as an acid basis may be derived from the chlorine now in the ocean less what was supplied during geological time by solution of the rocks.

Referring to Sir John Murray's table,[1] we deduce from the amounts of chlorides supplied annually by river discharge[2] (applying the deduction of 10 per cent. before mentioned to the sodium chloride) that the rivers contribute annually $75{\cdot}5 \times 10^{6}$ tonnes of chlorine. If now our final estimate of the earth's age is 95×10^{6} years, the total supply by denudation has been 7169×10^{12} tonnes of chlorine.

The total mass of chlorine now in the ocean, calculated on Professor Dittmar's table and the more recent estimate of the mass of the ocean (*ante*) less the amount calculated as above as supplied by the rivers subsequently, is $21{,}123 \times 10^{12}$ tonnes.[3] This amount we assume free to act as a primeval denuding agent.

According to Mr. F. W. Clarke[4] the older crust of the earth contained the following atomic percentages, which would be converted to chlorides by a primeval denudation such as we assume :—

	Percentage.		Percentage.
Aluminium . . .	8·13	Magnesium . . .	2·64
Iron	4·71	Potassium . . .	2·35
Calcium	3·43	Sodium	2·68

Dividing among these the mass of chlorine already estimated, we find that the chlorine taken up by the sodium would be 6·7 per cent. of the whole. This would amount to 1415×10^{2} tonnes, bringing $916{\cdot}7 \times 10^{12}$ tonnes of sodium into the primeval ocean.

Deducting this amount from the mass of sodium now in the ocean leaves $14{,}694 \times 10^{12}$ tonnes to be accounted for by subsequent denudation.

Of the other acid-forming substances possibly present in the primeval atmosphere and ocean, sulphur and carbonic anhydride need alone be referred to. The sulphur was, however, probably only free in small amount, if at all, being present in the average igneous crust[5] to the extent of 0·06 per cent., and being to-day supplied by denudation in quantities more than sufficient to account for all in the ocean. Considering that subdivision of its effects among the metals must also occur, an allowance is not called for.

Carbonic acid is a relatively feeble and slow rock solvent. Even if

[1] *Loc. cit.*

[2] As follows in tonnes per cubic kilometre :—

NaCl	4061
NH_4Cl	251
LiCl	600

[3] The chlorides now in the ocean are :—

NaCl	$39{,}703 \times 10^{12}$ tonnes
$MgCl_2$	5642×10^{12} tonnes

[4] *Bulletin*, U.S. Geological Survey, 148, p. 13.

[5] Clarke, *loc. cit.*

present in the abundance thought by some, its early effects were probably compensated by the more active effects of organic acids of later times. Vegetation, too, has been a source of carbonic acid in the soils during subsequent periods. It may be observed that the fixation of free CO_2 by vegetation so abundantly in the later Palæozoic and the increase in the deposits of limestone rather point to a gradual fixation of this substance than to any special activity as a solvent in earlier times. On these accounts we make no correction for the possible presence of this substance in primeval times.

Rock solution in heated waters persisted for periods relatively so short as to cause negligible error only. According to Lord Kelvin's calculation as to the rate of cooling of the solidifying crust, a period of a century would have been adequate to cool the crust from its melting-point down to about 8° Centigrade above what it would be without any underground heat. Hence, if the mean rate of solvent denudation was as much as a thousand times what it is to-day, the result would have been the accomplishment of 100,000 years' denudation in the first hundred years. If now we even lengthened the period of this excessive denudation, ten times the correction would be no more than about 1 per cent.

(b) *For Direct Marine Denudation.*—So far as the sea has directly acted on the coasts, and on the sediments deposited in it, an error is introduced calling for a subtractive correction on our estimate of geological time; in other words, upon our numerator, which is that part of the sodium in the ocean supplied by sub-aërial denudation only.

The total tide-swept area of the ocean is calculated by Sir J. Murray and Professor Renard ('Challenger' Report) as 162×10^3 square kilometres. The 'rainy' area of the land is about 113×10^6 square kilometres. The ratio of areas is 1 : 700. Hence, the assumption of a marine solvent denudation having an intensity twenty times that progressing over an equal area exposed to normal sub-aërial denudation would involve a subtractive correction of rather under 3 per cent. on geological time.[1] The solvent effects on sediments falling into the nearly, or quite, quiescent waters beyond this zone are assumed to be small on the grounds of the rapid flocculation and consolidation of marine sediments, as well as from the fact that the very minute mineral particles of oceanic sediments show little of such effects as would arise under conditions of sub-aërial denudation. They preserve, in fact, their soda in substantial excess of their potash. There is in marine sediments generally almost complete absence of the more active acid and oxidising effects progressing in the soils. Nor will the state of consolidation of marine sediments allow us to assume anything like the enormous surface area, as much as 500 square metres per litre, exposed within the soils.

On these grounds it is assumed that the correction should not exceed 6 per cent., nor be less than 3 per cent.

Our numerator was left at $14{,}694 \times 10^{12}$ tonnes, and our denominator at $15{,}542 \times 10^4$ tonnes. The resulting age of the earth would be 94×10^6 years. A subtractive correction of 4 per cent. for marine denudation leaves the geological age at 90×10^6 years. Future extension of our knowledge on the many points raised will, however, modify this number. Thus, according to Professor De Lapparent's[2] more recent estimation of

[1] See abstract of a paper read by the author before Section C, 'Some Experiments on Denudation in Fresh and Salt Water.'

[2] *Traité de Géologie*, tome i. p. 60.

the volume of the ocean, its mass is $1{\cdot}539 \times 10^{18}$ tonnes. This would raise our result by nearly 6 per cent.

We sum up the results of our inquiry, then, in the statement that the probable age of the earth, estimated from solvent denudation, is between ninety and one hundred millions of years.

Rock-salt Deposits from the Ocean negligible.

The amount of chloride of sodium in the ocean is sufficient to cover the entire land area with a layer of solid salt 122 metres deep. Compared with so great a mass the rock-salt deposits on the land are negligible. They are, moreover, only in part derived from the ocean, the circumstances leading to abstraction of salt from the ocean and its retention upon the land being exceptional. Likeness in chemical composition is no proof that bedded salts were derived from the ocean. Thus the proportions of salts in the Great Salt Lake are much the same as in the sea.[1]

So far as these deposits are derived from the denudation of 'rainless' regions, and are being gradually conveyed by rivers to the ocean, they constitute part of the normal supply of sodium to the sea.

Uniformity of sub-aërial Denudation.

The uniformitarianism involved in the present mode of calculating the age of the earth is broadly restricted to the approximate persistence throughout the past of the present sub-aërial association of water and rock.

The rate of solution of the rock-forming silicates is so slow that the abundance of the solvent or its rate of renewal is a relatively unimportant factor compared with the surface area exposed. Thus within certain limits climate will not seriously affect the question.

The existence of a rainless area, amounting to one-fifth the land surface, subject to extreme conditions of dryness secures that subsidence or elevation of land does not necessarily involve corresponding changes in the area of active solvent denudation. In the first case the more active margin moves inwards, in the second case it moves outwards.

The argument that the surface materials of the land areas must have been growing poorer in alkalies throughout geological time is met by the fact of the less resistent nature of sedimentary rocks, involving soils richer in soluble constituents. These are, in fact, more rapidly formed and removed. Observation shows that on comparing soils from the most diverse kinds of rocks the rapidly concentrated soils of limestones, or those derived from sandstones, very generally exceed in percentage of alkalies soils derived from igneous rocks.[2] It is within the soils that the chief work of solvent denudation is accomplished.

Confirmation in the Soda-content of the Igneous and Sedimentary Rocks.

We assume in our present argument necessarily that the sedimentary rocks were derived from the igneous in the process of denudation, a certain loss, representing matter gone into solution, occurring. Taking this loss into account, we may recover from the estimated mass of the siliceous detrital sedimentaries on the earth's surface the approximate total mass of the parent igneous rock. This represents a certain mass of soda

[1] *Nature*, December 28, 1899, p. 204.

[2] E. G. Merrill, *Rocks, Rock-weathering, and Soils* (Macmillan), 1897, pp. 305, 306, 358, and 359.

(deducible from our knowledge of the mean igneous rock-crust) which is to be accounted for between what is now represented in the ocean by the chlorides and what remains over in the detrital sedimentaries. Upon making the calculations, we find that the sum of the soda in the ocean and in the sedimentaries would nearly suffice to effect the full restoration of this constituent to the original rock. There is not quite enough.

The bulk of the siliceous sedimentaries is assumed to be represented by a layer 1·77 kilometres deep spread over the land area. This on a specific gravity of 2·5 affords a mass of 64×10^{16} tonnes, which we assume to be 67 per cent. of the mass of the parent rock.[2] Hence the parent rock possessed a mass of $95 \cdot 5 \times 10^{16}$ tonnes. We restore to this the soda equivalent of the sodium now in the ocean, $21 \cdot 0 \times 10^{15}$ tonnes. The mean soda-content of these sedimentaries determined on the analyses of over one hundred typical siliceous sedimentary rocks given in Professor H. Rosenbusch's *Elemente der Gesteinslehre* (Stuttgart, 1890) is found to be 1·47 per cent. This affords $9 \cdot 4 \times 10^{15}$ tonnes in the layer 1·77 kilometres thick. Restoring this also, the parent mass of igneous rock is found to have possessed 3·20 per cent. of Na_2O. According to Mr. F. W. Clarke (*loc. cit.*), the mean igneous rock contains 3·61 per cent. of soda.

This approximate agreement between the amount of sodium in the ocean and that missing from the sedimentary rocks is a confirmation of the validity of the present mode of deducing the age of the earth. It is directly opposed to the assumption of an ocean primevally charged with sodium salts. The negation is the more emphatic, seeing that the loss revealed by the sedimentary rocks of geological time appears to be *more* than sufficient to account for what sodium is to-day in the sea.

Plankton and Physical Conditions of the English Channel.—Second Report of the Committee, consisting of Professor E. Ray Lankester (*Chairman*), Professor W. A. Herdman, Mr. H. N. Dickson, *and* Mr. W. Garstang (*Secretary*), *appointed to make Periodic Investigations of the Plankton and Physical Conditions of the English Channel during* 1899.

The series of periodic surveys for which provision was made at the Bristol and Dover Meetings has been completed by Mr. Garstang, under the same conditions as were described in the First Report of the Committee. Since the Dover Meeting two surveys were carried out, viz., in November 1899, and in the first week of March 1900, thus making five quarterly surveys altogether.

It has been found impossible to finish the examination of the large quantity of material collected in time for report at the Bradford Meeting. The Committee therefore desire to be reappointed (without a grant) in order that they may present their final report at the Glasgow Meeting.

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[1] Merrill, *loc. cit.* pp. 209–225.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Professor E. RAY LANKESTER, Professor W. F. R. WELDON, Professor S. J. HICKSON, Mr. A. SEDGWICK, Professor W. C. MCINTOSH, *and* Professor G. B. HOWES (*Secretary*).

ON entering upon the year's occupancy of the Naples Table the advisability suggested itself of sending a circular letter to teachers and others likely to recommend workers; and as the result a greater number of applications were received than it was possible to grant. Among those which were entertained no fewer than three ultimately overlapped during spring, and the best thanks of the Committee are hereby tendered to Dr. Dohrn for his magnanimity, exceeding all precedent, in having arranged for the accommodation of all workers recommended, this notwithstanding. The indebtedness of the Committee is further increased by his having, on their behalf, granted Professor Ramsay Wright, of the University of Toronto, permission to spend the leisure of two months' residence in Naples in the study of the methods of capture and preservation in vogue in the bay, with a view to their application at the New Canadian Marine Station, the project for which received the support of the British Association. And this has been further increased by his having allowed Miss A. Vickers to collect seaweeds between October and January, on the recommendation of the Committee.

The list of British workers at the Naples Station which accompanies this Report exceeds, as regards numbers, all previous records, while that of naturalists of other countries reaches for the year seventy-four in all, bringing the total of those who have profited by the resources of the establishment since 1873–74, when Professor Waldeyer and the late Francis Maitland Balfour began work there, to nearly 1,200 persons.

The recent addition to the laboratory of a filter, by which half the sea-water in circulation in the tanks is filtered and separated from

the rest, has materially increased the facilities for experimental work now greatly in vogue ; and the fishing capacity is now sufficient to provide from fifty to sixty workers at a time with all requisite material. In every department of the establishment, laboratory and library alike, thorough efficiency and complete success have to be recorded.

Your Committee hereby apply for a renewal of the grant of 100*l.* to enable Mr. H. H. Stewart, M.A., to work at the Annelids, and to aid him and other competent researchers whom it is hoped to secure to study these and other organisms they may desire to investigate.

Appended to the Report is a note by the Chairman of the Committee *à propos* of a visit to the Station and his own Report on the Occupancy of the Table.

APPENDIX I.

Note by the Chairman *of the British Association Committee.*

As it is about ten years since a Chairman of this Committee visited the Naples Zoological Station, and reported on the condition of the institution,[1] it may serve a useful purpose to draw attention here to the facilities for work at this world-renowned laboratory, and to the additions and improvements effected during the last decade. I am indebted to Dr. Dohrn, the Director, and to the Secretary, Mr. Linden, for much information given me during my recent visit.

Since Dr. Sclater's visit in 1890 additional accommodation has been obtained by a re-arrangement of the roof of the main building. This gives space for a second laboratory, a supplementary library, and various smaller rooms used as chemical and physiological laboratories, for photography and bacteriology. A good deal of the research in recent years, both on the part of those occupying tables and of the permanent staff, has been in the direction of comparative physiology, experimental embryology, and the bacteriology of sea-water, and all necessary facilities for such work are now provided.

The number of work-places, in some cases separate rooms, known technically as 'tables,' is about fifty-five, and of these about thirty-four are rented annually by States, Universities, or Associations. Germany takes about ten of these, and Italy seven. There are three American tables, and three English (rented by the Universities of Cambridge and Oxford and the British Association respectively) ; consequently there are generally about half a dozen English and American biologists at work in the station ; but Dr. Dohrn interprets in a most liberal spirit the rules as to the occupancy of a table, and, as a matter of fact, during my recent visit there were, for a short time, no less than three of us occupying simultaneously the British Association 'table,' and provided with separate rooms.

A work-table is really a small laboratory fitted up with all that is necessary for ordinary biological research, and additional apparatus and reagents can be obtained as required. The investigator is supposed to bring his own microscope and dissecting instruments, but is supplied with alcohol, acids, stains, and other chemicals, glass dishes, and bottles of various kinds and sizes, drawing materials, and mounting reagents.

[1] *Nature*, February 1891, p. 392.

Requisition forms are placed beside the worker on which to notify his wishes in regard to material or reagents, he is visited at frequent intervals by members of the staff, and all wants are supplied in the most perfect manner.

The Staff of the station consists of :—

1. Dr. Anton Dohrn, the founder and director.
2. Seven scientific assistants—viz. Dr. Eisig, Administrator of the Laboratories ; Dr. Paul Mayer, Editor of the Publications ; Dr. Giesbrecht, assistant editor and supervisor of plates ; Dr. Gast, assistant editor and supervisor of microscopic drawings ; Dr. Schöbel, Librarian ; Dr. Lo Bianco, administrator of fisheries and préparateur ; Dr. Hollands, temporarily in charge of the microscopic sections department—all of them well-known men, each eminent in his own line of investigation. The post of assistant in the Physiological Department, formerly held by the late Dr. Schoenlein, is now vacant ; and in addition to the foregoing there are :—Secretary, Mr. Linden ; two painters, and the engineer ; with attendants, collectors, and others employed in the laboratories, in the collecting and preserving departments, Aquarium, and elsewhere.

This seems at the first thought a very large staff, but the activities of the institution are most varied and far-reaching, and everything that is undertaken is carried to a high standard of perfection. Whether it be in the exposition of living animals to the public in the wonderful tanks of the 'Acquario,' in the collection and preparation of choice specimens for Museums, in the supply of laboratory material and mounted microscopic objects to Universities, in the facilities afforded for research, or in the educational influence and inspiration which all young workers in the laboratory feel in each and all of these directions, the Naples station has a world-wide renown. And the best proof of this reputation for excellence is seen in the long list of biologists from all civilised countries who year after year obtain material from the station or enrol as workers in the laboratory. Close on 1,200 naturalists have now, since the opening of the Zoological Station in 1873, occupied work-tables, and as these men have come from and gone back to practically all the important laboratories of Europe and America, from St. Petersburg to Madrid, and from California to Japan, Naples may fairly claim to have been for the last quarter-century a great international meeting-ground of biologists, and to have exercised a stimulating and co-ordinating influence upon biological research which it would be difficult to over-estimate.

The opportunities for taking part in collecting expeditions at sea are most valuable to the young naturalist. Dredging, plankton-collection, and fishing are carried on daily in the Bay of Naples by means of the two little steamers belonging to the station, and a flotilla of fishing and other smaller boats. Many of the Neapolitan fishermen are more or less in the employ of the station, or bring in such specimens as they find in their work.

But although the work of the Naples Zoological Station is thus many-sided, the leading idea is certainly original research. An investigator goes to Naples to make some particular discovery, and he goes thither because he knows he will find material, facilities, and environment such as exist nowhere else in the same favourable combination. The British Association Committee consider it most important that these opportunities for research should be open to British biologists in the future as they have

been in the past, and it is on this ground that they confidently recommend the policy of sending selected investigators to Naples each year—a practice which has led to such satisfactory results in the past and is full of promise for the future.

APPENDIX II.

Reports on the Occupation of the Table.

Report on the Occupation of the British Association Table at Naples, from October to December 1899–1900.

a. The Anatomy of the Flatfishes (*Heterosomata*). *By* H. M. Kyle, M.A., B.Sc.

During the period, from October to the third week in December, 1899, when I had the privilege of occupying the British Association Table at Naples, the special research which engaged my attention was the Anatomy of the Flatfishes (*Heterosomata*). The species examined there were the following :—

Citharus linguatula, L.
Rhomboidichthys mancus, Risso.
Arnoglossus Grohmanni, Bon.
Arnoglossus laterna, Walb.
Lepidorhombus Boscii, Gtr.
Scophthalmus unimaculatus, Risso.
Rhombus maximus, Kl.
Solea vulgaris, Quens.
Solea lascaris, Risso.
(*Solea Kleinii*),
Solea ocellata, L.
Microchirus variegata, Don.
Microchirus minuta, Parn.
Monochirus hispida, Cos.
Ammopleurops lacteus, Gtr.

In addition to the above, through the courtesy of the Naples staff, I was able to examine several species of other families of the Teleosts, as well as the eggs, larvæ, and young of fishes to be found at that season.

The main conclusions arrived at have been embodied in a paper entitled : 'On the Classification of the Flatfishes (*Heterosomata*),' which is in process of publication in the Scottish Fishery Board's Report for 1899. In this paper it is shown that *Citharus linguatula*, a species very common in the Mediterranean, is a transitional form between the Halibut and Turbot groups of Flatfishes. The characters employed as tests of relationship are chiefly the position and structure of the ventral or pelvic fins, the position and structure of the olfactory organs, and the position of the eyes. Further, although *Citharus* is the only form in European waters which marks the transition between these two main groups, the American fauna possesses many similar forms, and the classification has therefore been altered in order to include these within one group or subfamily. It is also shown how the various subfamilies of the Flatfishes are restricted to fairly well-marked zones of distribution.

In conclusion, I wish to offer my best thanks to the Committee of the British Association for the opportunity granted me of pursuing my studies at Naples, and also to the authorities of the station for their kindness and courtesy.

Report on the Occupation of the Table in the Zoological Station at Naples, during part of December 1900.

b. The Structure of certain Polychæte Worms. By E. S. GOODRICH, *M.A. Oxon.*

During a short visit to Naples last winter, I occupied the Table of the British Association at the Zoological station. I have to thank the Committee for this opportunity of continuing my researches on the structure of Polychæte worms.

My observations were restricted almost entirely to the study of living specimens of *Alciopids*, *Phyllodocids*, *Polygordius*, and *Saccocirrus*. A considerable amount of material was also preserved for future use.

The nephridia of the Alciopids were found to closely resemble those of the Phyllodocids, having no internal cœlomic opening, and being provided with bunches of flagellated cells, the solenocytes. The genital products are carried to the exterior by ciliated genital funnels, which at maturity open into the nephridial ducts. A detailed description of these organs is about to be published in the 'Quart. Journ. of Micr. Science.'

Some details were also added to our knowledge of the nephridia of *Polygordius*; and the structure of the interesting, but little known, *Saccocirrus* was carefully investigated. The results of this study, which is not yet completed, will, I hope, shortly be ready for publication.

Report on the Occupation of the British Association Table at Naples during March and April 1900.

c. Observations on Compound Ascidians. By W. A. HERDMAN, *D.Sc., F.R.S.*

I occupied the British Association Table for a little over three weeks in March and April, 1900, with the object of examining in the living condition certain Mediterranean Compound Ascidians. Probably the first thought that occurs to any one who has worked at the Naples Zoological Station, on recalling the time he spent at that celebrated laboratory, is one of gratitude to Dr. Dohrn and his excellent assistants for their personal kindness and help, and of admiration for their highly efficient administration. I feel that if other workers desire to express their gratitude, I especially should do so, for it is probable that I gave unusual trouble at a busy period, and it seemed to me that I was treated with exceptional kindness. In addition to Dr. Dohrn, I desire to thank especially Dr. Eisig and Dr. Lo Bianco. With the latter I was brought largely into contact by the nature of my work.

During the recent short visit, my intention was mainly to see and examine as many species and specimens of Compound Ascidians as possible in the living condition, and then have them killed and preserved for histological work later. I was given excellent facilities for collecting in the small steamer *Johannes Müller*, belonging to the station, and twice —sometimes three times—every day fresh supplies of material, brought in by the fishermen, were placed in my aquaria.

The Compound Ascidians of the Bay of Naples have not yet been monographed. Some species were described by Delle Chiaje and others long ago, when the genera were imperfectly known and anatomical characters were not recorded. Other species have been briefly diagnosed more recently (but without any figures) by Della Valle. It is now almost impossible in many cases to tell from these descriptions alone which of

the Mediterranean species agree with those of the French coast described by H. Milne-Edwards, Giard, and Lahille, and with our British species.

I wished, therefore, to compare these published, but sometimes insufficient, descriptions with living specimens from the original localities in order to determine, if possible, the systematic positions of the species and provide myself with figures and anatomical details for comparison with British species. Fortunately, also, I found that Dr. Lo Bianco had in his stores a few of Della Valle's type specimens, or at least specimens of these species identified and labelled by Della Valle himself. These I was permitted to draw and examine. In regard to the other species, of which there were no authenticated specimens, I soon found that from the large number of examples they laid before me I was able in most cases to determine what form the original describer had before him. I then made coloured drawings of that form and examined its anatomy to settle to which modern genus it belonged, and samples of every species I examined and drew were preserved for histological purposes. In this way I hope I have secured the material necessary for an accurate comparison of a number of the Mediterranean and British species. I have brought back over thirty sheets of coloured figures, and Dr. Lo Bianco is sending a collection of bottles to Liverpool.

The following is a list of the species [1] I examined and determined when at Naples :—

ASCIDIÆ COMPOSITÆ.

I.—Merosomata.

Fam. 1.—Distomidæ.

Distomum costæ, Della Valle
crystallinum, Ren.
pancerii, Della Valle
Cystodytes della-chiajiæ, Della Valle
Distaplia magnilarva, Della Valle
rosea, Della Valle

Fam. 2.—Polyclinidæ.

Circinalium concrescens, Giard
Amaroucium roseum, Della Valle
crystallinum, Ren.
Aplidium gibbulosum, Sav.
Fragarium areolatum, D.Ch.

Fam. 3.—Didemnidæ.

Didemnum bicolor, V. Drasche
gelatinosum, Giard
cereum, Giard
Leptoclinum maculatum, M.-Edw.
coccineum, V. Drasche
perforatum, Giard
dentatum, Della Valle
fulgens, M.-Edw.
candidum, Della Valle
commune, Della Valle
gelatinosum, Giard
exaratum, Grube

Fam. 4.—Diplosomidæ.

Diplosoma crystallinum, Giard
Pseudodidemnum listerianum, M.-Edw.
Astellium spongiforme, Giard

II.—Holosomata.

Fam. 1.—Botryllidæ.

Botryllus tapetum, Della Valle
morio, Giard
aurolineatus, Giard
Polycyclus renieri, Lamk.
Botrylloides luteum, V. Drasche
rubrum, M.-Edw.
gascoi, Della Valle

[1] To complete the record the few simple Ascidians which were brought to me with the compound, and which I examined, have been included.

ASCIDIÆ SIMPLICES.

Fam. 1.—CLAVELINIDÆ.

Clavelina lepadiformis, O.F.M.
Diazona violacea, Sav.
Rhopalœa neapolitana, Phil.

Fam. 2.—ASCIDIIDÆ.

Ascidia mentula, L.
Ciona intestinalis, L.
Phallusia mammillata, Cuv.

Fam. 3.—CYNTHIIDÆ.

Cynthia dura, Heller
Microcosmus vulgaris, Heller
Styela canopoides, Heller
Polycarpa glomerata, Alder
Forbesella tessellata, Forbes

Report on the Occupation of a Table at the Zoological Station at Naples during March and April 1900.

d. The Anatomy of Phyllirhoë, the Cœlenterate Plankton, and certain Cœlenterata. By R. T. GÜNTHER, *M.A., Magdalen College, Oxford.*

The Committee of the British Association permitted me to use the Table hired by the British Association during the summer months of the present year, for the prosecution of certain researches on pelagic organisms in which I have been for some time and am at present engaged. Since it was inconvenient for me to work at Naples during the months of May and June, I was, by the generous courtesy of the Director of the Zoological Station, permitted to commence the occupation of the Table during my Easter vacation at a time when the resources of the station are very severely taxed by the great concourse of zoologists who annually assemble there at that season. For this especial act of kindness, in addition to so many others I have been shown by Dr. Dohrn, I desire to offer my hearty thanks.

The Table of the British Association was occupied by me for about a month—between March 24 and April 25, 1900.

My attention was principally devoted to a detailed study of the anatomy of *Phyllirhoë* and to a daily examination of the Cœlenterate portion of the plankton of the bay. The general character of the latter was very similar to what it was on a former occasion when I had the good fortune to examine it, but owing to the prevalence of westerly winds during parts of March and April, an unusual quantity of *Velella* and *Physalia* appeared in the bay. All along the sandy foreshore of Cuma, which is open to the west, sea and beach were remarkably delimited by *Velellæ* extending as a blue band about a foot or so broad and many miles in length. In consequence, too, of the same prevailing winds *Physalia*, which is extremely rare at Naples, and which has not been taken for twelve years, as I am informed by my friend Cav. Lo Bianco, appeared in great numbers, and was probably drifted in from the Atlantic as a consequence of the exceptional meteorological conditions.

I availed myself of the opportunity of verifying the statement that the characteristic blue colouring-matter of *Velella* (zoocyanin) may be very conveniently extracted from the tissues by maceration in a saturated solution of potassium acetate. A solution prepared on March 26, which has been kept in the dark, still retains its blue colour, and will be submitted to spectroscopic examination on my return to England. As the result of the action of the potassium acetate, the 'yellow cells' or symbiotic algæ, which are yellow in the tissues of the *Velella*, turn green. In several of the species examined the arrangement of these yellow cells was in groups of 2, 4, 8, or other multiples of 2.

Among other observations upon *Cœlenterata*, I have observed the existence of a continuous longitudinal strip of cells with granular protoplasm situated in the ectoderm and extending along one side of the tentacles of certain *Hydrozoa*. I have demonstrated the existence of this band of cells in the tentacles of the medusæ of *Carmarina* and in those of the hydropolyps of *Obelia*, *Eudendrium*, and *Aglaophenia*, and I have no doubt that it can be demonstrated in other genera also. This band of specialised cells can be made obvious by keeping the living animals for some time in sea-water tinted by methylene blue in the proportion recommended by Zoja.[1] It was found that certain cells along one side of the tentacles became stained, thus demonstrating the existence of the above-mentioned band of differentiated histological elements.

I was enabled to make very considerable progress with my work on the anatomy of *Phyllirhoë*, and to make several observations on the living animal, which I hope to publish before the close of the present year.

Report on the Occupation of a Table at the Stazione Zoologica, Naples, during March and April 1900.

e. The Fertilisation Process in Echinoidea.
By A. H. Reginald Buller, *Ph.D.*

I occupied the table of the British Association from March 15 until April 21.

The research work undertaken was an endeavour to determine whether the eggs of the *Echinoidea* excrete a fluid which attracts the spermatozoa chemotactically. Bergh[2] states that attraction by a special substance is probable. According to Strasburger[3] the eggs of the *Fucaceæ* (which are also fertilised after being set free in sea-water) excrete a substance which attracts the spermatozoa from a distance equal to about two diameters of an egg.

The material consisted of the following animals :—*Arbacia pustulosa* Gray, *Echinus microtuberculatus* Blv., and *Sphærechinus granularis* Ag.

No attraction could be observed during artificial fertilisation experiments. Collections of spermatozoa, however, take place in the outer gelatinous coat of the eggs. Observations were made tending to show that this is a physical and not a chemotactic phenomenon.

Experiments were then made in which it was sought to collect in sea-water the supposed fluid excreted from the eggs. The eggs were left very thickly placed together for 2–12 hours in a very shallow layer of sea-water, and the latter, after filtration, introduced by means of an air-pump into capillary glass tubes. These were then placed in a drop containing motile spermatozoa. No gathering of the spermatozoa into the tubes could be observed. One precaution taken was to prove that just before filtration the eggs could be fertilised.

In the case of *Arbacia* it was discovered that when spermatozoa are introduced into a drop containing freshly extruded eggs they collect into small balls, often composed of 100 or more individuals. The balls were also formed after the water had received four successive filtrations. A tactile stimulus appears to play a part in the phenomenon.

[1] In his experiments on Hydra, *Rend. Inst. Lomb.* xxv.
[2] *Vorlesungen über allgemeine Embryologie*, 1895, p. 43.
[3] *Das botanische Practicum*, 2te Aufl. 1887, p. 402.

When a sufficient number of spermatozoa have penetrated the gelatinous coat of an egg and have become attached by their heads to the layer which is subsequently raised and forms the vitelline membrane, rotation of the egg takes place. During the rotation, which may be in any direction, the gelatinous coat does not also rotate.

By means of the capillary tube method an attempt was made to find some substance which attracts the spermatozoa. Various substances, known to give a chemical stimulus to other organisms, were tested: meat extract, peptone, cane-sugar, glycerine, asparagine, alcohol, oxalic acid, nitric acid, potassium nitrate, sodium chloride, potassium malate diastase, and distilled water. No definite chemotactic attraction could be observed in any case.

The chief results arrived at were:—

1. The spermatozoa of the *Echinoidea* are not attracted to the eggs by means of any special substance excreted by the latter. The vast number of spermatozoa and the large size of the eggs are sufficient to ensure the necessary contact taking place.

2. It is not improbable that the spermatozoa are unable to respond to chemical stimuli by change in the direction of movement.

It gives me much pleasure to acknowledge my indebtedness to the staff of the Stazione Zoologica for supplying me with material and apparatus during the research.

Report on the Occupation of a Table at Naples.

f. The Methods of Preservation of Specimens used at the Zoological Station. *By* Professor R. RAMSAY WRIGHT.

In answer to my request that I might be permitted to avail myself of the arrangement existing between the British Association Committee and the Naples Zoological Station, the Secretary of the Committee was good enough to recommend me to the kind offices of the Director, Dr. A. Dohrn.

Although the British Association Table was already occupied, I found Dr. Dohrn anxious to make special arrangements for my accommodation, and I accordingly took advantage of these from December 20 till the end of February.

My object being to familiarise myself with the methods in use at the station, as well as with the Naples fauna in a living condition, I was installed in a room adjacent to that of Dr. Lo Bianco. Thanks to his intimate and extensive faunistic knowledge and to his untiring willingness to impart the results of his long experience in the conservation of marine animals, I felt at the close of my ten weeks' stay more than satisfied with the results I attained. As Dr. Lo Bianco was engaged at the time in giving instruction in methods to a medical officer of the German Navy, I was enabled to share these demonstrations and to acquire some expertness in dealing with those forms which, like the Siphonophora, had long proved refractory to attempts at preservation until Dr. Lo Bianco succeeded in elaborating the methods at present in use.

I hope to be able in the near future to utilise the technical experience gained at the New Canadian Marine Laboratory which has recently been brought to the notice of the British Association.

While expressing my thanks to your Committee, as well as to Dr. Dohrn and the various members of the staff of the Zoological Station, for the many courtesies shown me, I desire to record my opinion of the high efficiency of the station and of the convenience to British naturalists incident to the partial support thereof by the British Association.

APPENDIX III.

A List of Naturalists who have worked at the Zoological Station from July 1, 1899, *to June* 30, 1900.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
1109	Dr. F. Capobianco	Italy	July 1, 1899	—
1110	Prof. F. S. Monticelli	„	„ 12, „	Nov. 15, 1899
1111	Dr. Paul Juge	Switzerland	„ 14, „	Aug. 21, „
1112	Prof. G. Corrado	Italy	„ 22, „	—
1113	Dr. Sabussow	Russia	„ 23, „	„ 21, „
1114	Prof. F. Sanfelice	Zoolog. Station	„ 24, „	Nov. 4, „
1115	Dr. E. Germano	„ „	Aug. 4, „	—
1116	Prof. A. Russo	Italy	„ 10, „	„ 1, „
1117	Dr. F. Mazza	„	„ 11, „	Sept. 14,
1118	Dr. E. Crisafulli	„	„ 15, „	—
1119	Dr. G. Bottaro	Zoolog. Station	„ 15, „	—
1120	D. A. De Simoni	„ „	„ 24, „	Nov. 4, „
1121	Dr. J. Sobotta	Prussia	Sept. 1, „	Oct. 22, „
1122	Dr. F. Bottazzi	Italy	„ 6, „	„ 29, „
1123	Dr. P. Enriquez	„	„ 8, „	„ 29, „
1124	Dr. K. Reuter	Prussia	„ 20, „	„ 28, „
1125	Mr. F. B. Sumner	University Table	„ 25, „	Nov. 3, „
1126	Dr. H. Driesch	Hamburg	Oct. 7, „	May 24, 1900
1127	Dr. C. Herbst	Prussia	„ 7, „	„ 30, „
1128	Mr. E. Gurney	Oxford	„ 9, „	—
1129	Miss A. Vickers	*British Association*	„ 13, „	Jan. 14, „
1130	Dr. F. Nissl	Baden	„ 23, „	„ 6, „
1131	Prof. A. Biedl	Austria	„ 24, „	Dec. 19, 1899
1132	Mr. H. Kyle	*British Association*	„ 25, „	„ 17, „
1133	Miss S. Nichols	American Women's Table	„ 27, „	June 8, 1900
1134	Dr. H. Waldow	Zoolog. Station	Nov. 2, „	Mar. 1, „
1135	Prof. Taschenberg	Prussia	„ 17, „	Dec. 1, 1899
1136	Dr. v. Lingelsheim	„	„ 22, „	Mar. 1, 1900
1137	Miss E. Gregory	American Women's Table	„ 29, „	June 8, „
1138	Prof. F. Cavara	Italy	Dec. 1, „	Jan. 4, „
1139	Dr. Rina Monti	„	„ 4, „	„ 30, „
1140	Dr. M. Pierantoni	„	„ 14, „	—
1141	Mr. W. Cooper	Cambridge	„ 17, „	„ 14, „
1142	Mr. E. Goodrich	*British Association* and Oxford	„ 18, „	„ 11, „
1143	Prof. Ramsay Wright	*British Association*	„ 19, „	Mar. 1, „
1144	Dr. G. Jatta	Zoolog. Station	Jan. 1, 1900	—
1145	Dr. G. Vastarini Cresi	Italy	„ 1, „	—
1146	Dr. V. Diamare	„	„ 1, „	—
1147	Dr. G. Tagliani	„	„ 1, „	—
1148	Prof. T. D'Evant	„	„ 1, „	—

A LIST OF NATURALISTS—*continued.*

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
1149	Dr. A. Romano	Italy	Jan. 1, 1900	—
1150	Dr. G. Rossi	,,	,, 1, ,,	—
1151	Dr. H. Redeke	Holland	,, 6, ,,	Mar. 19, 1900
1152	Dr. V. Heiser	Smithsonian Table	,, 7, ,,	—
1153	Dr. H. Przibram	Austria	,, 21, ,,	June 15, ,,
1154	Dr. O. v. Fürth	Strassburg	,, 30, ,,	April 3, ,,
1155	Miss H. Snowden	American Women's Table	Feb. 1, ,,	Mar. 29, ,,
1156	Dr. B. M. Duggar	Smithsonian Table	,, 27, ,,	Apr. 9, ,,
1157	Dr. G. Senn	Switzerland	,, 27, ,,	,, 3, ,,
1158	Cand. T. Bergmann	Prussia	Mar. 3, ,,	,, 25, ,,
1159	Dr. H. Winkler	Würtemberg	,, 3, ,,	,, 19, ,,
1160	Dr. O. zur Strassen	Saxony	,, 12, ,,	,, 20, ,,
1161	Dr. A. Buller	*British Association*	,, 14, ,,	,, 22, ,,
1162	Dr. R. Hoffmann	Prussia	,, 14, ,,	,, 19, ,,
1163	Dr. R. Woltereck	Saxony	,, 15, ,,	,, 20, ,,
1164	Mr. C. F. Hottes	University Table	,, 16, ,,	Mar. 27, ,,
1165	Prof. Zimmermann	Switzerland	,, 16, ,,	Apr. 16, ,,
1166	Prof. Herdman	*British Association*	,, 19, ,,	,, 9, ,,
1167	Dr. J. Sobotta	Bavaria	,, 21, ,,	,, 19, ,,
1168	Mr. R. Günther	*British Association*	,, 23, ,,	,, 26, ,,
1169	Dr. W. Magnus	Hesse	,, 24, ,,	,, 3, ,,
1170	Signa. C. Losito	Italy	,, 24, ,,	,, 27, ,,
1171	Dr. M. Bedot	Switzerland	,, 27, ,,	,, 27, ,,
1172	Prof. Ballowitz	Prussia	Apr. 4, ,,	,, 21, ,,
1173	Dr. T. H. Ashworth	Cambridge	,, 7, ,,	June 16, ,,
1174	Sir Ch. Eliot[1]	*British Association*	,, 11, ,,	Apr. 18, ,,
1175	Prof. D. Carazzi	Italy	,, 27, ,,	—
1176	Dr. P. Cerfontaine	Belgium	May 2, ,,	—
1177	Herr H. Fischer	Würtemberg	,, 7, ,,	June 8, ,,
1178	Dr. S. Mollier	Bavaria	,, 20, ,,	—
1179	Prof. T. H. Morgan	Smithsonian Table	June 15, ,,	—
1180	F. B. Sumner	University Table	,, 20, ,,	—
1181	Stud. C. de Dawÿdoff	Russia	,, 22, ,,	—
1182	Dr. J. Boeke	Holland	,, 22, ,,	—

APPENDIX IV.

A List of Papers published in 1899 *by Naturalists who have occupied Tables in the Zoological Station.*

A. Fischel . . . . Ueber vitale Färbung von Echinodermeneiern während ihrer Entwickelung. Anat. Hefte, Abth. 1, Bd. 11, 1899.

G. Jatta . . . . Sopra alcuni Cefalopodi della Vettor Pisani. 'Boll. Soc. Nat. Napoli,' vol. 12, 1899.

H. Driesch . . . . Die Localisation morphogenetischer Vorgänge. Arch. für Entw.-Mech. Bd. 8, 1899.

[1] Cf. last year's Report.

H. Driesch . . . Quantitative Regulationen bei der Reparation der Tubularia. *Ibid.* Bd. 9, 1899.

„ . . . Notizen über die Auflösung und Wiederbildung des Skelets von Échinodermenlarven. *Ibid.*

J. Ogneff . . . Prof. Gilson's Cellules musculo-glandulaires. Biol. Centralblatt, Bd. 19, 1899.

R. Hesse . . . Untersuchungen über die Organe der Lichtempfindung bei niederen Thieren. V. Die Augen der polychaeten Anneliden. Zeitschr. f. wiss. Zoologie. Bd. 65, 1899.

S. Garten . . Beiträge zur Physiologie des electrischen Organs der Zitterrochen. Centralbl. f. Physiologie, Bd. 13, 1899, and Abh. Sächs. Ges. Wiss., Bd. 25, 1899.

H. L. Jameson . . Thalassema papillosum, a forgotten Echiuroid Gephyrean. 'Mitth. Zool. Station, Neapel,' Bd. 13, 1899.

S. Metalnikoff . . Das Blut und die Excretionsorgane von Sipunculus nudus. *Ibid.*

B. Solger . . . Mauthner'sche Fasern bei Chimaera. Morphol. Jahrbuch, Bd. 27, 1899.

„ . . . Zur Kenntnis des Gehörorgans von Pterotrachea. Schr. Naturf. Gesellsch., Danzig, Bd. 10, 1899.

L. Schultze . . . Die Regeneration des Ganglions von Ciona intestinalis. Jen. Zeitschr., Bd. 33, 1899.

Th. Pintner . . . Nectonema agile Verrill. Akad. Anzeiger, No. 10, Akad. Wiss. Wien, 1899.

G. Mazzarelli . . . Intorno al tubo digerente ed al 'centro stomato-gastrico' delle Aplisie. Zool. Anz., Bd. 22, 1899.

J. von Uexküll . Die Physiologie der Pedicellarien. Zeitschr. für Biologie, Bd. 37, 1899.

„ . . Die Physiologie des Seeigelstachels. *Ibid.* Bd. 39, 1899.

Th. Beer . . . Vergleichende physiologische Studien zur Statocystenfunction. II. Versuche an Crustaceen. Archiv f. d. ges. Physiologie, Bd. 74, 1899.

A. Bethe . . . Die Locomotion des Haifisches (Scyllium) und ihre Beziehungen zu den einzelnen Gehirntheilen und zum Labyrinth. *Ibid.* Bd. 76, 1899.

F. Schütt . . Centrifugales Dickenwachsthum der Membran und extramembranöses Plasma. Jahrb. Wiss. Botanik. Bd. 33, 1899.

E. Albrecht . . . Untersuchungen zur Structur des Seeigeleies. Sitz. Ber. Ges. Morph. Phys. München, Bd. 14, 1899.

G. Bitter . . . Zur Anatomie und Physiologie von Padina pavonia. Berichte D. Botan. Ges., Bd. 17, 1899.

„ . . . Zur Morphologie und Physiologie von Microdictyon umbilicatum. Jahrb. Wiss. Botanik, Bd. 34, 1899.

V. Diamare . . . Studii comparativi sulle isole di Langerhans del Pancreas. Internat. Monatschrift f. Anat. und Physiol., Bd. 16, 1899.

„ . . . Sul valore anatomico e morfologico delle isole di Langerhans. Anat. Anzeiger, Bd. 16, 1899.

F. Bancroft . . . A new function of the vascular ampullæ in the Botryllidæ. Zool. Anzeiger, Bd. 22, 1899.

G. Schneider . . . Ueber Phagocytose und Excretion bei Anneliden. Zeitschr. Wiss. Zool., Bd. 66, 1899.

M. Nordhausen . . Zur Anatomie und Physiologie einiger rankentragender Meeresalgen. Jahrb. Wiss. Botanik, Bd. 34, 1899.

H. M. Vernon . . The death temperature of certain marine organisms. Journal of Physiology, vol. 25, 1899.

„ . . The effect of staleness of the sexual cells on the development of Echinoids. Proc. Royal Soc., vol. 65, 1899.

A. Beck. . . .	Ueber die bei Belichtung der Netzhaut von Eledone moschata entstehenden Actionsströme. Archiv f. d. ges. Physiologie, Bd. 78, 1899.
C. Herbst . . .	Ueber die Regeneration von antennenähnlichen Organen an Stelle von Augen. III. and IV. Archiv f. Entw. Mech., Bd. 19, 1899.
W. Stempell . . .	Zur Anatomie von Solemya togata Poli. Zool. Jahrb. Spengel, Abth. Anat. u. Ontog., Bd. 13.
W. Lindemann . .	Ueber einige Eigenschaften der Holothurienhaut. Zeitschr. f. Biologie, Bd. 39, 1899.
F. Röhmann . . .	Einige Beobachtungen über die Verdauung der Kohlenhydrate bei Aplysien. Centralblatt f. Physiol., 1899.
E. Küster . . .	Gewebespannungen und passive Wachsthum bei Meeresalgen. Sitz. Ber. Akad Wiss. Berlin, 1899.
F. Bottazzi . . .	Ricerche fisiologiche sul sistema nervoso viscerale delle Aplisie e di alcuni Cefalopodi. Rivista Scienze Biologiche. Vol. 1, 1899.

APPENDIX V.

A List of the Publications of the Zoological Station during the year ending June 30, 1900.

1. Fauna und Flora des Golfes von Neapel.' Asterocheriden, by W. Giesbrecht. 216 pp., 11 plates.

2. 'Mittheilungen aus der zoologischen Station zu Neapel.' Vol. xiv. parts 1 and 2, with 10 plates.

3. 'Zoologischer Jahresbericht' for 1898.

4. 'Guide to the Aquarium.' A new German edition has been published.

Index Animalium.—Report of the Committee, consisting of Dr. HENRY WOODWARD (*Chairman*), Mr. W. E. HOYLE, Mr. R. MCLACHLAN, Dr. P. L. SCLATER, Rev. T. R. R. STEBBING, *and* Mr. F. A. BATHER (*Secretary*).

THE Committee has the honour to report that this work has made very satisfactory progress in the hands of Mr. C. Davies Sherborn, and that the literature down to the year 1800 has now been sought out and indexed. The manuscript of this portion will be ready for the printer in a few weeks, and the Committee is considering the best form of publication and estimating the cost. Meanwhile the indexing of literature after 1800 is being continued. At this stage the Committee would be glad to receive suggestions or offers of help for the publication of this great work, since the sums hitherto so generously awarded to it are only sufficient for the necessary current expenses, which continue as before. The Committee therefore earnestly requests its reappointment, with a grant of 100*l*.

Natural History and Ethnography of the Malay Peninsula. Report of the Committee, consisting of Mr. C. H. READ (*Chairman*), Mr. W. CROOKE (*Secretary*), Professor A. MACALISTER, *and* Professor W. RIDGEWAY.

THE Committee have received the following report from Mr. W. W. Skeat, the leader of the expedition :—

Report on Cambridge Exploring Expedition to the Malay Provinces of Lower Siam. Drawn up by W. W. SKEAT.

This expedition was organised to carry out a scientific survey, in which Ethnology, Zoology, Botany, and Geology should all have a share, of the little-known Malay provinces of Lower Siam, and especially to extend the scope of the ethnographical collections and observations referred to in the Fourteenth Annual Report of the Antiquarian Committee to the Senate (June 6, 1899).

The party comprised Messrs. R. Evans, of Jesus College, Oxford; F. F. Laidlaw, of Trinity College, Cambridge; D. T. Gwynne-Vaughan, of Christ's College, Cambridge; R. H. Yapp, of St. John's College, Cambridge; N. Annandale, of Balliol College, Oxford, and myself.

The inhabitants of these provinces are, for the most part, Malay, but Siamese influence becomes gradually predominant to the northward, and the process of fusion between these two antagonistic elements presents some curious racial problems. But the most interesting subject for investigation in these provinces is perhaps presented by the very primitive jungle tribes of the interior, about whom much valuable information was obtained.

Yet another interesting tribe, of whom no account seems to have yet been published, is the sacred tribe of the Prâms, who claim to have come over from India, and to have established themselves in the country anterior to the coming of the Siamese or Malays. What truth there may be in their statements will (it may be hoped) now be ascertainable, as a copy of their sacred book, containing an account of their origin, was obtained by the expedition.

But the special interest of the territories traversed centres, perhaps, in the fact that they have hitherto formed a species of ethnical backwater, but little, if at all, affected by the ideas of a higher civilisation. These ideas, however, are already taking root, and many of the manners and customs witnessed by the expedition are becoming obsolescent or are already obsolete.

It is hoped that when the results are known the present expedition will be found to have achieved results to some extent comparable with those obtained by the important expedition sent by the Dutch Government to Mid-Sumatra in 1877–9. The results obtained should also be of value, for purposes of comparison, with the results of the very successful Cambridge Anthropological Expedition of Dr. Haddon to the Torres Straits, Sarawak, and New Guinea.

Owing to the uncertainty as to the probable reception which the expedition would experience at the hands of the inhabitants, the good offices of the Siamese Government were bespoken by the Foreign Office;

and I have much pleasure in recording the extreme hospitality and enlightened help which the expedition consequently received from the local authorities, in some cases, perhaps, under rather difficult circumstances. The warmest thanks of those interested in the expedition are due to H. E. Phya Sukhum, the High Commissioner for the Ligor Circle of the Siamese-Malay States; to Luang Phrom and Kun Rât, the special commissioners attached to the expedition as escort; to the Commissioners and Rajas of Patalung, Singora, Patani, Raman, Jala, Jering, Nawng Chik, Ligeh, Teluban, and Kelantan, the Sultan of Kelantan, the Sultan of Trengganu, and the Sultan and Raja Muda of Kedah.

We reached Singora on March 27, 1899, and were most hospitably entertained in his own house by the High Commissioner, H. E. Phya Sukhum. Next day we proceeded up the Inland Sea. This is a very shallow lake, or, perhaps, rather chain of lakes, part of which is salt and part fresh water. It measures, roughly speaking, some sixty miles in length, and in the broadest part is not less than twenty miles wide. Some dredging was done here by Messrs. Evans and Annandale, and the Bird's Nest Islands were visited, observations made, and photographs taken of the curious cave-dwellings of the island guards.

At Lampam (Lumpumm) a short stay was made by Messrs. Evans and Vaughan, Mr. Annandale and myself proceeding into the interior to try to meet with a small Sakei (jungle) tribe of Pangans who were reported to have been seen in the vicinity, and to photograph some of the Siamese tree-graves, which method of burial, in accordance with instructions from Bankok, is fast becoming obsolete. A forced march by night on elephants brought us to the spot too late to overtake the wild men, who had moved away, no one could say whither, the night before our arrival. Mr. Annandale was able, however, to photograph their late dwelling-place, which consisted of a cave under a projecting rock, near the summit of a lofty hill. He also took photographs of the tree-graves. These are usually cigar-shaped wrappers, or rather 'shells' made of laths, and suspended horizontally at a height of 6 to 8 feet from the ground between two tree-trunks, branches, or posts. The corpse is exposed in one of these shells (the heels being generally left higher than the head), and allowed to decay till the bones are clean, after which the bones should be collected and burnt. Box-like receptacles on posts (as among the Madangs of Borneo) are occasionally substituted for the wrappers. On this journey some strange articles of diet were served up to us, among them being red ants, toads, bee-grubs, and a species of cicada. The manner in which the latter are caught is peculiar. Two or three natives gather at night round a brightly burning wood fire, one of them holding a lighted torch. The others clap their hands at regular intervals, and the cicadæ, attracted by the noise and guided by the light, fly down and settle upon the people as they stand by the fire. In the 'wat' (Siamese temple) at Ban Nah Mr. Annandale noticed that one of the small figures of Buddha which had been deposited in the temple as an offering, contained a fossil shell, and this clue, carefully followed up, led to the discovery of the quarry from which the fossil had been taken. The formation is of the Cretaceous age, and a number of specimens showing fossiliferous traces were secured here; well-authenticated finds of fossils in the Malay Peninsula have been of the rarest possible occurrence.

On this same journey a couple of young leopard- or panther-cubs were picked out of their nest in a hollow tree by the roadside, and it being

found difficult to feed them they were, on reaching Lampam, suckled by a Siamese woman, who claimed to have previously suckled a bear. On reaching Lampam we found that Messrs. Evans and Vaughan had proceeded to the 'Tālē Noi,' or 'Little Lake, at the end of the Inland Sea, and followed them accordingly. We did not overtake them, but our visit to the 'Little Lake' was of great interest. In one of the local 'wats' or temples a human embryo was found among the offerings. We also came upon a small isolated tribe called 'Prâm' (? Brahm) people, who claimed to be a sacred tribe of Indian origin, and appear to have been hitherto undescribed. They retained several peculiar customs, notably that of burying their dead in a sitting posture, with the top-knot tied to the top of the coffin. A copy of a sacred book, describing the origin of the tribe and the story of their migration, was obtained with difficulty. It is said to be written in an Indian language, which they themselves no longer understand. Their dress consisted of a white robe, a white shoulder-cloth, and a peculiar white two-peaked turban or cap. Their chiefs claimed that they were the oldest inhabitants of the country, and that they were not constrained to make obeisance even to the sovereign.

After a few days' further stay in Singora, where we rejoined Messrs. Evans and Vaughan, we proceeded to Patani in the commissioner's yacht, arriving after a good passage just in time to witness part of the gorgeous pageantry of a Malay 'royal' wedding, between the Raja of Patani's sister and the 'Raja Muda' of Kelantan.

At Patani we were lodged in a big brick building ordinarily used as a school. An unfortunate accident here greatly handicapped the photographic work. A big iron-bound shutter fell from its fastenings with a crash inside the building, and striking our best camera, so injured it that it had to be sent to Europe for repairs, a matter of months, and an irreparable loss so far as photographic work was concerned. It had just been used for taking a photograph of the Raja of Patani, who had most fortunately just returned to his house. Mr. Evans also had a narrow escape.

On the 28th we left for Bukit Besar, or Negiri (Indragiri), an isolated mountain about 3,000 feet high, on which several days were spent. This was known to the natives as a haunted mountain possessing a pond near the summit, on which are said to grow certain magical shrubs, one of which is believed to be the means of conferring perennial youth on its finder, and another to be one of the most powerful love-charms in the world. These treasures are guarded by a host of demons, and the natives expressed great fear of them until the ascent to our camp (at a height of about 2,000 feet) had been successfully accomplished, after which their fears rapidly subsided. Mr. Evans got his first specimen of *Peripatus* here, and Mr. Vaughan also did well with the mountain flora.

On our return to Patani Messrs. Vaughan, Annandale, and Evans proceeded up the Patani to Biserat in Jalor (Jalå), which proved an excellent collecting-ground. I stayed at Patani for some days longer, and visited the very extensive saltpans near the river mouth, the Patani potteries, and the grave and shrine of the celebrated local saint of Cape Patani, about all of which much information was gained. Of the latter many miracles are told, and his grave-posts (at the head and foot) are still believed to make prophetic movements, one instance of which I was enabled to test on the spot. Two very curious rods, such as are used in divination, were here obtained.

On the 26th I rejoined the rest of the party at Biserat, and then visited the magnificent limestone caves, a very complete collection of whose fauna was made by Mr. Annandale. These caves included the fine Gûa Gambar, or Statue Cave, which contains a recumbent figure of Buddha, nearly 100 feet long, as well as a number of other statues in a sitting posture. Extensive zoological and botanical collections were also made at Biserat by Messrs. Evans and Vaughan. An exhibition of devil dancing was here witnessed.

Smallpox having now set in badly and two deaths occurring in the village, collecting became more difficult, and presently the Raja and his household retired to the hills, and many houses were closed by means of a rattan, carried round outside the fence of the compound, whilst slipknots of jungle-grass (lalang) were hung across the gate, and a couple of stems of a bitter-tasting tree, called the Bedara Pahit, buried crosswise on the threshold.

One of the annual ceremonies for the purification of a village was here witnessed, and many ethnological specimens and much information obtained. On June 6 Mr. Evans fell ill, and as he took long to recover, Messrs. Annandale and Vaughan proceeded to Kota Bharu, in Raman, whilst Mr. Evans and I went down to the coast.

After spending a few days at Patani, we went to Jambu in Jering. Here, too, I witnessed the annual ceremony for the purification of the village, at which the launching of a spirit-boat, about a yard and a half long, formed the chief feature. Before leaving Jambu I paid a flying visit to Teluban. On returning to Patani we were rejoined by Messrs. Vaughan and Annandale, and proceeded by the overland route through Raman Ligeh and Ulu Kelantan, and up the Lebih, a tributary of which stream, the Aring, takes its rise in the neighbourhood of the Tahan Mountain, which it was one of the objects of the expedition, if practicable, to ascend. The expedition therefore started from Biserat on July 6, and proceeded to Kota Bharu, the chief town of Raman.

Halts of some days' duration for transport purposes were made at Kota Bharu, Tremangan, Belimbing, and Aur Gading (a village below the rapids on the Lebih river), but on August 10 the expedition reached the village of Kuala Aring, having covered in thirty-five days (only about half of which were spent in travelling) a distance of about 200 miles. The first eighty or ninety miles were performed on elephant back, the remainder by means of boats or bamboo rafts. Mr. Vaughan, who had only joined the expedition for the first six months, left us at Belimbing.

At Kuala Aring I found the local authorities so opposed to giving information about the route to the mountain that it appeared to me safer to try to find the way for myself than to put the expedition at the mercy of local guides. I therefore left Messrs. Evans and Annandale at the village, and set out to scout with two of the Malays belonging to the expeditionary staff I decided to attempt the mountain from the Pahang side, and ascending the Lebih to its headwater crossed the watershed by way of Bukit Batu Atap, and descending the tributaries of the Tembeling eventually reached a village called Kampong Pagi, where I spent four or five days in fruitless attempts to obtain guides from the wild tribes in the neighbourhood. They were afraid to go, but I obtained the services of six of the local Malays as carriers (two of whom absconded at the end of the first day's march), and proceeded up the banks of the Tahan river until the foot of the mountain was reached. My original plan was to

ascend some of the high crags in the vicinity of the mountain, and thus ascertain its locality, but at the end of the first week's march, finding that we were on what appeared to be a spur of the main range, I decided to go forward and ascend it as far as circumstances would permit. We therefore climbed the range peak by peak, but were at length stopped by a formidable subsidence or break, which forced us to return on our tracks for a day's march before we could circumvent it. Eventually, after a march of about eleven days since our entry into the river, we reached the highest point that we could compass, about 200 feet to 300 feet below the peak, when we were stopped by an overhanging wall of rock which, after several attempts, we found ourselves unable to scale or circumvent. We got sight, however, here of a hitherto unrecorded companion peak to the Tahan Peak, which was identified as Gunong Larong, or 'Coffin Mountain.' At this time we had barely enough rice even on short rations to last three days, and the descent, till we reached the nearest human habitation, took five. Our difficulties were further increased by fog, rain, and fever.

The rains were exceptionally heavy, the Tahan river being three times in flood during our ascent of the mountain, and as they had set in earlier than usual, it appeared, under the circumstances, unadvisable and unsafe to commit the rest of the expedition to the ascent of the mountain.

Mr. Annandale therefore, who had been waiting at Kuala Aring with a view to participating in the ascent of the mountain, if practicable, returned to Europe, and Mr. Evans remained in camp with Mr. Yapp, who had arrived during my absence. Mr. Laidlaw accompanied me up the Aring river, and there took photographs and full measurements of several persons belonging to the wild tribes, while a good deal of information about their manners and customs, as well as a vocabulary of nearly 600 words, was collected by myself.

On our return, we all descended the Lebih on rafts, as far as its juncture with the Kelantan river, and thence descended the latter as far as Kota Bharu, the capital of the important East Coast State of Kelantan, and the seat of its Raja.

On the way down the river we measured and photographed several more Sakeis. At Kota Bharu Messrs. Laidlaw and I stayed for about a month, Messrs. Yapp and Evans proceeding to Trengganu, in order to pay a short visit to the coral islands off that coast.

Much important ethnological work was done at Kota Bharu. Investigations were conducted into Malay methods of industry, and a devil-dancing performance was witnessed by Mr. Laidlaw and myself, at which the name of the winning bull at a coming bull-fight was correctly prophesied. Full anthropological measurements were taken by Mr. Laidlaw of ten or twelve Kelantan Malays, notes made of the colour of their skin, eyes, hair, &c., and experiments made as to their colour vision.

On leaving Kota Bharu we proceeded to Trengganu, where we met Messrs. Evans and Yapp, who reported having had a narrow escape from drowning off the Redangs through the swamping of their boat. Mr. Evans was unable to swim, but I am thankful to say that both he and Mr. Yapp succeeded in holding on to the boat until they were picked up by some Malays, who went to their assistance. They were about half a mile from shore at the time.

At Trengganu my investigation of Malay industries was continued, and much useful information obtained. The most interesting was perhaps

the method of manufacturing damasked krisses—the details of which were carefully studied. Measurements were also taken of at least ten of the Trengganu Malays, and full observations recorded.

On leaving Trengganu, we proceeded to Singapore, where a few days were spent, and a visit paid to one of the villages of the 'Orang Laut' (the old piratical stock of sea-gipsies, who were once the terror of the Straits, and who were found by Sir Stamford Raffles living in their boats round about the island of Singapore, when it was proclaimed a British Colony).

By the first available steamer we proceeded to Penang, whence Mr. Evans proceeded to Pulau Bidan, an island off the Kedah coast, to collect marine zoological specimens, and Messrs. Yapp and Laidlaw made the ascent of Gunong Inas (a hill, upwards of 5,800 feet high), in Perak, a difficult trip, the successful accomplishment of which reflects credit on Mr. Yapp, who, as the senior member of the staff after Mr. Evans's departure, took charge of the remainder of the party in my absence. They both brought back with them extensive collections (zoological and botanical). Mr. Evans returned to Penang on Christmas Eve, having used up the remainder of his outfit, and returned to Europe a few days later, having completed his year's work.

As soon as I was able to go up country, I proceeded to Kedah, and there, after a short excursion up the coast to Satal and Perlis, made two expeditions into the Sakei country, near the headwaters of the Muda. Here I had the good fortune to find a tribe of from twenty to thirty individuals living in a long barrack-like shelter of palm-leaves. From them, and from a neighbouring tribe, I obtained much valuable information as to their manners, customs, and language, as well as full measurements of a few individuals, and some probably unique phonographic records of their songs, which are of an extremely simple and primitive character. I also, with difficulty, procured the skeleton of an adult male. In all the States visited by me, investigations were made into the leading Malay industries, and much valuable material bearing on this subject was collected. Wherever possible, statistics were obtained showing the extent and nature of the development of trade and the stage of civilisation which had been reached by the people. Many of the leading Malay industries, such as that of weaving, are being rapidly modified by the introduction of European methods and appliances, and it is now the rarest and most difficult thing to obtain cloth actually made of home-spun thread, the use of Singapore silk and aniline dyes being already almost everywhere the fashion.

In addition to the above, the departments of ethnology studied included religious and medical ceremonies, children's games, legends, languages and dialects, under each of which headings a mass of material was collected.

The Zoology of the Sandwich Islands.—Tenth Report of the Committee, consisting of Professor NEWTON (*Chairman*), Dr. W. T. BLANFORD, Professor S. J. HICKSON, Mr. F. DU CANE GODMAN, Mr. P. L. SCLATER, Mr. E. A. SMITH, *and* Mr. D. SHARP (*Secretary*).

THIS Committee was appointed in 1890, and has been annually re-appointed.

In accordance with the intention announced in the last report, Mr. R. C. L. Perkins has again been sent to the islands by the Committee. His departure from this country was delayed for some months by the outbreak of plague at Honolulu; but this difficulty having disappeared, he is now at work in the island of Kauai.

Four parts of the second volume of the 'Fauna Hawaiiensis' have been published since the last report. They comprise 441 pages and 14 plates, the subjects and authors being as follows: 'Orthoptera and Neuroptera,' by R. C. L. Perkins; 'Coleoptera,' pt. 1, by D. Sharp and R. C. L. Perkins; 'Mollusca,' by E. R. Sykes; 'Earthworms,' by F. E. Beddard; 'Entozoa,' by A. E. Shipley.

Mr. Perkins finds that great changes have taken place in the islands during his absence, and that the forests are being extensively destroyed and replaced by sugar-cane, this industry being at present extremely remunerative there.

The Committee ask for reappointment.

Investigations made at the Marine Biological Laboratory, Plymouth.—Report of the Committee, consisting of Mr. G. C. Bourne (*Chairman*), Professor E. Ray Lankester (*Secretary*), Professor Sydney H. Vines, Mr. A. Sedgwick, Professor W. F. R. Weldon, *and* Mr. W. Garstang.

Messrs. Woodward, Scott, and Brebner were prevented from visiting Plymouth during the past year. Several other naturalists, however, applied for the use of the British Association's table, and it was accordingly allotted to Mr. A. D. Darbishire, of Balliol College, Oxford, for investigations on the development and natural history of *Pinnotheres*; and to Mr. W. M. Aders for the collection and preparation of material for studying the spermatogenesis of cœlenterates. Mr. Darbishire occupied the table for six weeks, and Mr. Aders for three weeks, during the past summer. Mr. Darbishire's report to the Committee is given below.

An application for the use of the table during the month of September has been received from Mr. R. C. Punnett, B.A., in order that he may continue some investigations on which he is at present engaged on the pelvic plexus of elasmobranch fishes.

Mr. Darbishire's Report.

My original intention was to study the life-history and habits of the crab *Pinnotheres*, which is a well-known inhabitant of mantle-cavities of certain lamellibranchiate molluscs; but during my visit to Plymouth no breeding females could be found, and my observations were limited to the determination of some new points in the habits and structure of the male of *Pinnotheres pisum*. A specimen of this was dredged in company with some *Cardium norvegicum*, from which it presumably came. The habits of the male were very interesting to observe in view of the sedentary habits of the female. It could swim forwards for a long time and at a good speed, and with an accurate sense of direction. It swam in a manner hitherto undescribed in crabs by rowing with its last two pairs of thoracic legs, each of which has a double row of hairs on its posterior

edge. As the female is said to be blind I made many experiments to determine the sensitiveness of the male to light. It was conclusively shown that the male is not only not blind, but is extremely sensitive to light in that it avoids extremes both of light and darkness, and in an area offering various degrees of illumination invariably takes up a moderately illuminated position.

As more specimens of *Pinnotheres* could not be found, I decided to study the myology of *Calanus*. It would be out of place to give here the details of the musculature of this copepod, but it is interesting to note that the arrangement and comparative size of the muscles tend to support Prof. MacBride's recent statements as to the movements of *Calanus* and other copepods, viz., by means of their second antennæ and pleopods, and not by means of their first antennæ. I tried numerous methods for demonstrating the muscles by using various stains, fixing agents, and mounting media. The most successful was to cut the animal in half sagittally, after fixation with corrosive sublimate, stain in borax carmine, and mount in glycerine jelly (Brady's solution). This shows the muscles of the trunk clearly.

I take this opportunity of thanking the British Association for the use of their table at the Plymouth Laboratory, and Mr. Garstang and Dr. Allen for their ever-ready help and suggestions.

Coral Reefs of the Indian Regions.—Interim Report of the Committee, consisting of Mr. A. SEDGWICK (*Chairman*), Mr. J. GRAHAM KERR, Professor J. W. JUDD, Mr. J. J. LISTER, *and* Mr. S. F. HARMER, *appointed to investigate the Structure, Formation, and Growth of the Coral Reefs of the Indian Region.*

THE Committee have received the following report from Mr. J. Stanley Gardiner :—

The expedition under my charge has been carrying out work during the last eighteen months in the Laccadives, Maldives, and Ceylon.

During the month of May 1899 I toured through the raised coral-reef areas of Ceylon and round the coast. In the north of the island these form a succession of higher and higher raised reefs down to Dambula, broken only by isolated flat-topped peaks of older rocks, on the sides of which the successive elevations are sometimes clearly visible in horizontal lines of wave action. It is only in the topography of the older, often much dolomitised country that the previous existence of either barrier or isolated reefs is indicated. The greater part is formed of a mixed reef sand, and appears before elevation to have borne a considerable resemblance to the large mudflats round the islands of Viti Levu and Vanua Levu, in the Fiji group.

Round the coast of Ceylon, especially to the south, a recent elevation of five to twenty feet was found in broad flats by the sea. These are now invariably being washed away down to the low-tide level, at which they persist, to a certain extent, as fringing reefs of varying breadth. The greater part of the west and south coasts is devoid, however, of any reef-growths, the shore being rocky or formed of fine siliceous sand. In May 1899 the rocky shore near Bentota was seen to be covered with

small coral colonies, which were evidently a growth of the previous north-east monsoon. In September these had completely disappeared, having been washed away in the south-west monsoon. At Galle, Talpe, and Weligama numerous recently living colonies of corals, particularly of the genera *Porites* and *Pocillopora*, of four to eight months' growth, were found completely silted up with sand and dirt of all sorts.

A noticeable point about the reefs immediately round Ceylon is the comparative absence of reef-building nullipores, which are a marked feature of all isolated oceanic reefs. In connection with this an attempt was made to examine the shoals two to six miles off the south and south-west coasts of the island, which indicate with the soundings the possible upgrowth of a barrier reef. The weather, however, at that season was so unfavourable that I was unable to dredge, land, or anchor on any.

Subsequent visits to south India and north Ceylon indicated clearly a former land connection between the two. The so-called Adam's Bridge and the islands of Manaar and Ramasserim, which the former joins, appeared indubitably to be the remains of a formerly elevated limestone flat, which has been more or less cut down by the sea to the low-tide level. The coast lines, too, of Ramasserim and to the north of the Jaffna peninsula were also probably at one time continuous.

The months of June, July, and August 1899 were spent in Minikoi, an isolated atoll, the most southern of the Laccadive group. Here I was accompanied by Mr. L. A. Borrodaile, who proposed to study various points connected with the Crustacea and Chætopoda. Unfortunately Mr. Borrodaile, who had been collecting these forms in Ceylon, almost at once succumbed to the climate, and after five weeks returned to Ceylon, whence he was at once ordered home. Every part of the island was visited: a survey was made and numerous cross-sections were run. From these it was clear that there had been an elevation of the original reefs to a height of at least twenty-five feet above low-tide level. Numerous observations were made on the currents at different depths within the lagoon in reference to its shoals, &c. Work on this point could seldom be carried on outside the reefs, as originally intended, owing to the heavy north-westerly winds which prevailed. The lagoon was dredged to ascertain the distribution of its corals, and a few water samples and temperature observations were taken.

Considerable attention was paid at Minikoi to the sand-feeding organisms, especially Holothuriæ, Enteropneusta, and Sipunculida. These forms appear to be largely instrumental in finely triturating the sand, the small particles being subsequently carried out of the lagoon in a state of suspension. The boring organisms, too, are very important in causing the decay of dead coral and rock, especially in the lagoon. These, accordingly, do not form points of attachment for fresh reef-growths to arise, and owing to the larger surface exposed are the more readily dissolved by the water. Indeed all evidence collected showed that the lagoons of atolls may be, and are, very generally formed by the solution of the central rock of originally more or less flat reefs.

In October 1899 I left for the Maldive group, to which I was accompanied by Mr. Forster Cooper, who assisted me in all the work and very largely took charge of the dredging. The Sultan lent us a schooner of about eighteen tons, which we at once fitted out in Male, subsequently cruising through the northern atolls during the months of November, December, and part of January. About a hundred islands in the atolls

of Goifurfehendu (Horsburgh), S. Mahlos, N. Mahlos, N. Miladummadulu, S. Miladummadulu, Fadiffolu, and Male were visited. Numerous soundings were made and dredgings everywhere taken. Horsburgh Atoll and the two atolls of Mahlos Madulu in particular were thoroughly worked over.

Parts of January and February 1900 were spent at Hulule, a small island at the south-east corner of Male Atoll, this being the month of Ramazan. A thorough survey of this island and its reefs was made, the whole forming an atoll of the second order, an atollon on the rim of an atoll. Large collections were obtained of the fauna of this atollon from all depths, together with observations on many special points. A set of corals of known period of growth was collected from an artificial passage through the reef to the landing-place of the island.

In February Mr. Forster Cooper took the schooner off for a short dredging cruise in Male Atoll, while I remained in Male making special observations on the water temperature, currents, food, &c.

In March I was unfortunately obliged, owing to illness, to return to Ceylon, where I spent some time in hospital. Mr. Forster Cooper meantime continued the work, taking the schooner and dredging the atolls of S. Male, Felidu, Mulaku, Kolumadulu, and Haddumati.

In April I returned with the s.s. *Ileafaee*, a vessel of about 350 tons, which I had chartered. Mr. Forster Cooper was relieved in Haddumati Atoll and joined the steamer, the schooner being sent back to Male. We then proceeded to Huvadu (Suvadiva) Atoll, which we entered by a northern passage. The lagoon to the east was dredged and sounded, the positions of islands and reefs observed, and four islands visited. A move was then made to Addu Atoll, the outer slopes of which and also the lagoon were dredged and sounded. The islands were charted in with the assistance of Captain Molony, and the majority were visited by some member of the party. On returning to Suvadiva the south and west sides of that atoll were dredged. On account of the heavy weather we were prevented from seeing Mulaku, which we had especially desired to visit.

Proceeding north to Male we skirted Haddumati Atoll and crossed Kolumadulu, then visited and dredged S. and N. Nilandu Atolls, subsequently anchoring in Felidu and Ari. The passages were sounded between the following atolls: Kolumadulu and S. Nilandu, S. and N. Nilandu, Mulaku and Wattaru, Wattaru and Felidu, N. Nilandu and Ari, S. and N. Male. Three further lines of soundings were run across the central basin between the east and west lines of atolls.

More than three hundred dredgings were taken, and in addition large and, we believe, very complete collections were made of the reef-fauna at Minikoi and Hulule, four natives at least always accompanying and assisting us in this work. The collections of land-fauna we believe to be equally complete from these islands. Collections of the plants of five separate Maldivan islands are now in the hands of Mr. J. C. Willis, Peradeniya Gardens, Ceylon.

A large number of anthropological measurements and considerable ethnological collections were procured, of which we hope to give the Association an account at some subsequent meeting.

Bird Migration in Great Britain and Ireland.—Third Interim Report of the Committee, consisting of Professor NEWTON (*Chairman*), Rev. E. P. KNUBLEY (*Secretary*), Mr. JOHN A. HARVIE-BROWN, Mr. R. M. BARRINGTON, Dr. H. O. FORBES, *and* Mr. A. H. EVANS, *appointed to work out the details of the Observations of Migration of Birds at Lighthouses and Lightships*, 1880–87.

REFERRING to its Interim Report of last year your Committee has the satisfaction of stating that Mr. William Eagle Clarke, of the Museum of Science and Art in Edinburgh, has been diligently continuing the laborious task he undertook of working out the details of the collected observations in accordance with the scheme indicated in the Report made at Bristol in 1898, and has furnished your Committee with the following Statement, together with a Summary of the observations as regards (I.) the Song-Thrush (*Turdus musicus*) and (II.) the White Wagtail (*Motacilla alba*), which throws such a light on the Natural History and especially the movements of those two species as has never been possessed before.

Your Committee feels that a great debt of gratitude is due to Mr. Clarke for the courage and perseverance which he has shown in grappling with the enormous mass of statistics necessary to afford the results so lucidly and concisely summed up by him. Your Committee trusts that its feeling may be shared by the Association generally, and that as a consequence a grant of money may be renewed, if only to defray the outlay which is involved by the prosecution of Mr. Clarke's labours. Remuneration for his invaluable services, which the Association will remark he is willing to continue, is unfortunately not to be thought of.

In its Report last year your Committee mentioned that one of its members (Mr. R. M. Barrington) was printing the results obtained from the Irish Lights, continued on his own account since 1887. That gentleman has since prepared for publication, at the cost of a stupendous amount of labour, an Analysis of these results, which he hopes will appear before the end of the year, and your Committee desires to call early attention to what cannot fail to be one of the most important contributions to the study of Bird Migration ever made.

Your Committee respectfully requests reappointment.

Statement furnished to the Committee.
By WM. EAGLE CLARKE.

The extraction of the records of occurrences of birds in Great Britain and Ireland, culled from the voluminous periodical and other literature published during the period covered by the inquiry, 1880–1887 inclusive, has at length been completed, and has resulted in many thousands of useful and important observations relating to the movements and occurrences of birds in both maritime and inland localities being added to the data amassed by the Committee.

This additional information includes not only a set of valuable records for the inland counties of Great Britain and Ireland, which was a great desideratum, but also comprises data relating to the occurrence of a con-

siderable number of rare and critical species made by ornithologists—data, in fact, that it was impossible to obtain from the light-keepers, whose knowledge of birds is, naturally, limited.

Since the year 1891 Mr. Harvie-Brown and myself, with the valued assistance of Mr. Lionel W. Hinxman and Mr. T. G. Laidlaw, have prosecuted an inquiry into the movements of birds in Scotland, and the investigations are still proceeding.[1] In addition to the observers at the light-stations, we have enlisted the services of a number of ornithologists. This again has resulted in the acquisition of much useful supplementary information.

Now that the data have been made as complete as possible, the time has arrived when, for the first time in the annals of British Ornithology, it is possible to write an authoritative history of the migrations of each British bird, for few indeed among our native species are entirely sedentary.

This is the task I now propose, with the approval of the Committee and of the British Association, to undertake.

I submit herewith a Summary of Details of the various migratory movements of two species—(I.) the Song-Thrush (*Turdus musicus*) and (II.) the White Wagtail (*Motacilla alba*)—as examples of my method of treatment.

Summary of Details.

I. *Song-Thrush* (Turdus musicus).

Introductory.—The Song-Thrush furnishes us with a most excellent example of the complex nature of the phenomena of bird migration as observed in Great Britain and Ireland.

The various movements of this species cover a period of nearly ten months of the year, June indeed being the only month in which the Thrush does not figure as a migrant in the records amassed by the Committee.

During this period it plays a varied *rôle* as a migratory bird, being a summer visitant, a bird of passage in spring and autumn, a winter visitant, a winter emigrant, and lastly, it is chiefly to be regarded as a rare casual visitor to the most northerly of the British Isles, namely, the Shetlands.

In addition, the Thrush is a permanent resident in certain districts, more especially in the gardens and immediate neighbourhood of cities and towns, where even in Scotland a number remain throughout the year. Such residents, however, probably form the minority of our British Thrushes.

Autumn Emigration of Summer Visitors.—At the end of summer[2] and in the early autumn a considerable number of the Thrushes which have reared their broods with us, especially those which inhabit the elevated districts, emigrate towards the south.[3]

[1] The Reports appeared in the *Annals of Scottish Natural History* for 1893, pp. 147–164; 1894, pp. 146–153; 1895, pp. 207–220; 1896, pp. 137–148; 1897, pp. 137–151; 1898, pp. 200–217; 1899, pp. 140–158; 1900, pp. 70–87.

[2] On July 8, 1882, five Thrushes struck the lantern at Slyne Head Lighthouse (west coast of Ireland), one of which was killed. In 1885, on July 3 and 11, several Thrushes are recorded at the Inner Farne. On all these occasions the weather was very unsettled, and thunder prevailed.

[3] Mr. T. G. Laidlaw, whose home in Peeblesshire lies 900 feet above the sea, informs me that the Thrushes leave that district 'to a bird' in the autumn, and return during the early months of the year.

Some of these may not proceed at once beyond our southern counties, where the length of their sojourn is determined by the climatic conditions of the season ; others depart forthwith for more southern regions beyond our limits.

Throughout August, but chiefly towards the end of the month, there are clear indications at the light-stations that Thrushes are quietly slipping away from Britain. There are no marked movements recorded for this month, but there is unmistakable evidence that a gradual and steady emigration is in progress on all the coasts of Britain. From the Irish coasts, however, this happens only rarely during August, the birds usually departing later in the season. These earliest emigrants are generally observed in small numbers, and either alone or occasionally in company with 'Warblers ;' sometimes a few are killed at the lanterns.[1]

In September and October the emigratory movements are more general and more pronounced in their nature ; but it is not until the weather breaks up in the latter month that any 'rush' is recorded. During these months, especially in September, the Thrush departs in company with various species of summer birds, and its emigrations are recorded from all sections of the British and the east and southern coasts of Ireland. The Thrush is, however, emigratory to a lesser degree in the Sister Isle than in Britain.

In October the migratory movements of the Thrush are often of a very complex nature, and are difficult to interpret. The most complicated movements are those during which emigration, immigration, and passage are in progress simultaneously, a phenomenon which sometimes happens under peculiar weather conditions.[2]

Later in the year the emigratory movements, which doubtless include many of the recently arrived immigrants from the north of Europe, are dependent on and synchronous with more or less severe weather conditions, and these will be duly treated of in the proper place.

Autumn Immigration and Passage.—There is no evidence whatever of the appearance of the Thrush upon our shores, as an immigrant from North-western Europe, until the end of the third or the beginning of the fourth week of September, when it arrives with great regularity[3] in company with the first Redwings (*Turdus iliacus*) ; occasionally Redbreasts (*Erithacus rubecula*), Goldcrests (*Regulus cristatus*), Woodcock (*Scolopax rusticula*), Jack Snipe (*Gallinago gallinula*), and Short-eared Owls (*Asio accipitrinus*) are observed at the same time.[4]

The immigrations continue during October, during which month there are lulls, followed usually by two very pronounced 'rushes' to our shores, when for several successive nights Thrushes pour in upon our eastern seaboard in vast numbers. These 'rushes' occur as a rule (1) about the middle of the month, and (2) again during its fourth week.

These immigratory movements are confined to the east coast of Britain, from the Orkneys to Norfolk. North Ronaldshay, the most

[1] As early as August 1, 1884, six Thrushes struck the lantern of Dhuheartach Rock Lighthouse, two being killed.

[2] See 'Digest of Observations,' *Brit. Assoc. Rep.*, 1896, p. 471.

[3] On September 21 in 1881, 1882, 1883, and 1887.

[4] Professor Collett, *Oversigt af Christiania Omegns ornithologiske Fauna*, p. 27, says that the Thrush departs from the Christiania district during September, and continues to do so until the first days of November. Statistics for S.W. Norway would be preferable, as being more intimately associated with those for Great Britain, but unfortunately they do not appear to be available.

north-easterly of the Orkneys, and the extreme southern portion of the main island of Shetland are annually visited, but these stations mark the northern limit of the Thrush's *regular* distribution during migration in Britain, for the bird is recorded very rarely further north, and is practically unknown in Unst. The Thrush's travelling companions are chiefly its congeners the Redwing (*Turdus iliacus*), Fieldfare (*T. pilaris*), Ring Ousel (*T. torquatus*), and Blackbird (*T. merula*); and also the Brambling (*Fringilla montifringilla*), Goldcrest (*Regulus cristatus*), Redbreast (*Erithacus rubecula*), Woodcock (*Scolopax rusticula*), &c.[1]

Along with these species many Thrushes perish at the lanterns of the lighthouses and light-vessels, especially when the night is hazy, with light rain.

Unlike its congeners just named, it is somewhat remarkable that the Thrush does not occur as an immigrant in numbers in November. The immigration of the Thrush practically ceases with the great arrivals which characterise the latter half of October, though stragglers do arrive up to the middle of November. After this the autumn immigration of the Thrush entirely ceases. Many of the immigrants upon arrival proceed south, as birds of passage, along our eastern and southern coasts, and finally quit our shores, the majority to seek more southern lands, others to cut across St. George's Channel to winter in Ireland. Others, again, remain as winter visitors, and work their way to Western Britain[2] and Ireland after an overland passage. Many of the birds, however, quit our islands, after a longer or shorter sojourn, under the pressure of severe weather conditions.[3]

Winter Movements.—The great emigratory movements of the winter commence in October,[4] and are continued during November, December, January, and February.[5] They are synchronous with outbursts of cold, snow, or of extremely unsettled weather. Such untoward conditions may prevail generally over our islands, or they may be circumscribed; and their influence on the emigrations of the Thrush is in more or less direct consonance with their distribution.

In genial months little or nothing is recorded. In others the few local movements are traceable to topical weather conditions. But sooner or later during each season great outpourings take place, often extending over several successive days and nights and affecting all our coasts. The Thrushes affected are not merely our would-be resident birds, but a very

[1] For the weather conditions controlling the movements of the British autumn immigrants, see the 'Digest of Observations,' *Brit. Assoc. Rep.*, 1896, pp. 469–471.

[2] The Thrush is a winter visitor only to certain isles off our western coasts, among others Tiree in the Inner Hebrides. From careful observations made on that island by Mr. Peter Anderson, we learn that this bird makes its first appearance there for the winter on dates varying from October 4 to 30, some considerable time after its first arrival on our shores.

[3] It has been stated that a small dark race of the Thrush occurs on passage on the east coast of England. These birds are supposed to be of Hebridean origin. I have never seen specimens of such a race, and I do not believe that they can have found their way to our eastern coast from the Hebrides. I have examined a number of Thrushes from Barra in the Outer Hebrides, where the bird is a resident, and do not find them to differ either in size or colour from the ordinary mainland form.

[4] In 1886, as early as October 4 and 6, there were great emigratory movements on all our coasts, due to extremely unsettled weather, with thunder in the N. and N.W., accompanied on the 5th by a great fall of temperature—a fall of fifteen degrees below that of the previous day.

[5] There are also movements during March in some years; but they are of a local nature, and are not to be regarded as emigratory.

large proportion of them are no doubt the immigrants lately arrived from the north, which, as winter visitors to our islands, remain until compelled to move further south or west.

The first move on these occasions is to the coast, where some tarry, and even remain to perish ; while others pass down both the east and west coasts of Great Britain, many of those following the former route, sweeping along the south coast westward, and crossing the Channel for the Continent. Many again seek Ireland, from which, however, emigrations are also recorded.

Should the cold spell be of great severity, or be unduly prolonged and widespread, then a still further exodus takes place (observed chiefly on the west coast of Great Britain and east coast of Ireland), and many perish even in such usually safe retreats as the Scilly Isles, and at Valentia, or other isles off the west coast of Ireland, which are largely sought on such occasions. No doubt, too, many of these emigrants perish in their continental haunts, for after winters of almost arctic severity, such as that of 1880–81,[1] the Thrush was conspicuous by its absence, or by its rarity, in most districts in our islands.[2]

Spring Immigration.—Among the voluminous records relating to the movements of this species during February, there are many which clearly indicate that the Thrushes which left us in the early autumn to winter in countries to the south of us commence their return to our islands for the spring and summer.

These immigrations are performed by small parties during mild periods of the month, and are chiefly observed on the southern coasts of England and Ireland.

Such return movements are continued during the first half of March, when immigrant Thrushes, in company with Blackbirds (*Turdus merula*), Larks (*Alauda arvensis*), Pipits (*Anthus pratensis*), Starlings (*Sturnus vulgaris*), Lapwings (*Vanellus vulgaris*), and Curlews (*Numenius arquata*), are recorded from the south coast of England northwards to the Western Isles of Scotland, and from the south and south-east coast of Ireland.

The arrivals on the south coast of England take place during the night or early morning. In Ireland they are recorded for both the hours of darkness and during the daytime, and the birds are noted as proceeding in a north-westerly direction at the south-east stations.

In most instances the return is a gradual one, performed by small companies, and at intervals, but occasionally in March in 'rushes' with the other species already mentioned.

Spring Emigration.—Towards the end of March the Thrushes which have wintered in Tiree and other western islands off the coasts of Scotland and in Ireland are recorded as taking their departure.

It is not, however, until April that the spring emigratory movements from the mainland of Britain set in. Then the birds which have wintered in our islands leave our shores to return to their summer haunts in Northern Europe.[3]

Throughout April, but chiefly during the first three weeks of the

[1] During this winter twenty days of hard frost and sixteen days of deep snow prevailed on the west coast of Ireland. It was much more severe elsewhere.

[2] Other severe seasons covered by the inquiry, during which great movements and much mortality among our Thrushes are recorded, are those of 1885–6 and 1887. The first half of March, 1886, was remarkably severe, and many Thrushes perished even in our southern counties.

[3] In 1885, on March 28 and 29, a few Thrushes in company with Blackbirds appeared at North Ronaldshay, the most north-easterly island of the Orkneys.

month, the emigratory movements of the Thrush are pronounced, and are almost entirely confined to the north-east coast of England and to the eastern and northern stations of Scotland. Some movements are also in evidence on the west coast of Britain, where the birds departing from Ireland and the Hebridean Islands are observed.[1]

On these occasions the Thrush is noted as emigrating in company with Blackbirds (*Turdus merula*), Fieldfares (*T. pilaris*), Redwings (*T. iliacus*), and Redbreasts (*Erithacus rubecula*).

During April the British emigratory movements doubtless become merged with those of the Thrushes which are on passage along our coast-line, proceeding from their more southern winter to their more northern summer quarters.

Spring Birds of Passage.—The first undoubted appearance of the Thrush as a bird of passage takes place at the end of March, when the birds which have wintered in South-western Europe, and are *en route* for breeding quarters to the north of our isles, arrive on the south coast of England in company with Blackbirds (*Turdus merula*), Fieldfares (*T. pilaris*), Redwings (*T. iliacus*), Wheatears (*Saxicola œnanthe*), 'Warblers' (*Sylviidæ*), Larks (*Alauda arvensis*), Starlings (*Sturnus vulgaris*), and, occasionally, Woodcocks (*Scolopax rusticula*).

These early arrivals do not appear to proceed to North-Western Europe *instanter*,[2] for, as we have stated, there are no March emigrations. The passage continues *throughout* April, when the *voyageurs* pass northwards along our eastern seaboard, where they are joined by many of our British emigrants of the same species; and it is often a matter of difficulty to distinguish between these classes of migrants during certain movements in April.

In the years 1881, 1883, and 1885 there were a few movements which carry the date of passage into May, the 10th of that month being the latest date on which the northern migration of the Thrush is recorded.[3]

Such is the history of the Song-Thrush as a British migratory bird, when the tangled skein of its various movements has been reduced to order through careful study.

The main facts elicited are:

1. That many Thrushes leave us at the end of summer and during the autumn, indicating that a very considerable number are summer visitors to our islands;

2. That the first immigrant Thrushes—winter visitors and birds of passage—appear on our shores from the N.E. during the latter days of September;

[1] Professor Collett, *Oversigt af Christiania Omegns ornithologiske Fauna*, p. 26, gives from the early to the last days of April as the period for the Thrush's arrival in spring in the Christiania district.

[2] From March 19 to 26, 1898, the Rev. O. Pickard-Cambridge, F.R.S., records an increasing number of Thrushes around his rectory at Wareham, on the coast of Dorset. On the 25th the land was fairly covered with them, and there must have been 200 or more in one field. On the 26th there were even more. On the 27th there were fewer, and by the evening of the 28th all had departed. *Zool.*, 1898, p. 264.

[3] 1881, May 2, Inner Farne, Thrushes at lantern with blackbirds (*Turdus merula*) and Ring Ousels (*T. torquatus*). 1883, May 8 and 10, at same station, in company with the same species; May 7, Flamborough Head, four killed. 1885, May 2, 3, 5, and 6, Pentland Skerries, with Ring Ousels (*T. torquatus*), Fieldfares (*T. pilaris*), and Redbreasts (*Erithacus rubecula*); 5th and 8th, Isle of May, several with 'Warblers' (*Sylviidæ*), Red-backed Shrike (*Lanius collurio*), and Ruff (*Machetes pugnax*).

3. That the great autumn immigrations from the Continent cease with the month of October, or considerably earlier than those of the Thrush's migratory congeners;

4. That winter emigratory movements, due to climatic pressure, set in with the first severe weather and recur with each outburst, but in gradually diminishing volume;

5. That the return spring immigratory movement of British and Irish Thrushes—summer visitors—from Southern Europe, commences in February and continues until the middle of March;

6. That the spring emigratory movements—the departures of winter visitors from Britain—for Northern Europe set in and are continued throughout April;

7. That the spring birds of passage arrive upon our shores from Southern Europe late in March, and that the passage proceeds during April, and, in some years, extends to the early days of May;

8. That the Thrush occurs annually on the British shores from Southern Shetland and North Ronaldshay southwards, and that these stations mark the northern limit of the bird's *regular* distribution as a migrant in Britain;

9. That migrants to and from North-western Europe arrive on, and depart from, our north-eastern and northern coasts, and that many birds of passage among them traverse our eastern and southern coasts on proceeding to their winter quarters (Continental and Irish) in the autumn and on their return in the spring;

10. That the autumn immigrants which winter with us reach Western Britain and, to a certain extent, Ireland after an overland passage;

11. That the west coast of Britain and the eastern and southern coasts of Ireland are those chiefly visited during the great migratory movements due to severe weather;

12. That Ireland is largely sought during the colder months, both by ordinary winter visitors and also by Thrushes driven out of Britain by severe climatic conditions;

13. That the Thrush does not participate in the east to west autumn, and west to east spring, movements across the southern waters of the North Sea.

II. *White Wagtail* (Motacilla alba).

The White Wagtail as a British migrant presents several points of interest.

As a summer visitor it is somewhat rare, and has only been recorded to breed occasionally in some of the more southerly counties of England.

It is chiefly as a bird of passage that it visits our islands, and is then *en route* to and from northern breeding haunts which lie both to the N.E. and N.W. of us, namely, in Scandinavia, Faroe, and Iceland. It occasionally reaches Southern Greenland.

As a migrant it is one of those species, few in number, which are more abundantly and generally observed on our western seaboard and its vicinity than on the east coast.

Spring Immigration.—The White Wagtail arrives on the south coast of England in small parties during March, sometimes during the early days of that month.[1]

[1] The earliest date with which I am acquainted relates to this bird's occurrence near Plymouth on March 3, 1872.

The immigrants continue to arrive on the English shores of the Channel until late in April, and in certain seasons have been observed in numbers on the west coast of Cornwall as late as the first half of May.

On arrival on our southern seaboard the birds, which are most abundant on the western section of that coastline, usually tarry for some little time before resuming their journeys. In due course, however, they pass inland or northwards along both the east and west coasts, especially the latter.

Spring Passage.—During March there are few records of the White Wagtail's appearance on either the east or west coast of Great Britain. With April, however, the regular passage northwards sets in, and continues until about the middle of May [1]—not beyond, so far as regular passage is concerned.

On the west coast we are able to trace the birds from Cornwall along the Welsh coast to the Solway and Clyde areas, and occasionally northwards to West Ross. 'Wagtails' are, however, observed regularly on passage at Cape Wrath, the N.W. limit of the mainland of Scotland, down to the middle of May. I have little doubt that these records relate to this species. Passing thence to the western islands, we pick up the lines of flight first at the important rock station of Skerryvore, and then at the Hebrides, in whose outer and inner islands, or certain of them, it is a bird of double passage. Here it has been observed at Barra, Monach, Lewis, Tiree, and Coll. At Barra (a southern island of the outer group) and at Tiree (one of the inner isles) it is quite common on passage in both spring and autumn; and from these stations we have during late years been furnished with a valuable set of observations, and have examined many Hebridean specimens obtained on both islands at each of the seasons.[2]

At the Monach Isle, with the exception of St. Kilda, the most western of the Hebrides, the White Wagtail is recorded as occurring not unfrequently during April and early May.

Intimately connected, no doubt, with these far western British movements are those observed in Ireland. Here, however, our present knowledge is only of a fragmentary nature, for the few observations made in the sister isle all relate to the coast and isles of a single county, namely, Mayo, where the White Wagtail has been occasionally seen on passage during April and early May.[3]

It is strange that there is not a single instance on record of the White Wagtail's occurrence on the east coast of Ireland, though I can scarcely bring myself to believe that the bird does not occur there on its migratory journeys.

Passing to the east coast of Great Britain, we find little or no information for its southern section, not even for that county which has always been remarkable for ornithological research and for its able ornithologists, namely, Norfolk. Here it appears to have occurred merely on two or three occasions, and in the springtime only.

[1] At the island of Tiree, Inner Hebrides, it has been observed passing north in considerable numbers as late as May 15.

[2] The following are the spring records for Tiree kindly furnished to Mr. Harvie-Brown and myself by Mr. Peter Anderson: 1893, April 7 and May 1; 1894, April 7, 12, and 30; 1895, May 3 and 5; 1896, April 22 and 24; 1897, April 28 and 30 and May 1 and 4 to 8; 1898, April 19 and 26; 1899, May 3 and 15 (many).

[3] The most important of these Irish movements was witnessed passing along the shores of Killala Bay early in May, 1898 (Saunders, *Bull. Brit. Orn. Club*, vii. p. 58).

In Lincolnshire and Yorkshire, so far as actual records are concerned, the White Wagtail is decidedly uncommon on passage in the spring.

It is not until we reach the coast of Haddingtonshire that we have any adequate information regarding the passage of the present species along the east coast. Here, thanks to information privately supplied to me by my friend Mr. Wm. Evans, it is possible to find the bird in numbers, sometimes in considerable numbers, *by looking for it*, in April and at the beginning of May. I have myself seen the bird in both spring and autumn on the southern shores of the Firth of Forth.

North of this the only definite record for the eastern mainland known to me refers to its occurrence at Inverness during April.

In the northern isles of Orkney and Shetland there are a considerable number of records of Pied Wagtails (*M. lugubris*) during the late days of April and early May, for the Pentland Skerries in Orkney and for Whalsey Skerries and Dunrossness in Shetland, which, I have little doubt, from the lateness of the dates, refer to the passage of the White Wagtail.[1]

Saxby [2] records the bird from Unst on two occasions in spring, namely, for June 1854 and May 1867. I am, however, not a little dubious as to the identity of certain migratory flocks of Pied Wagtails which that observer mentions as appearing in the spring on their way north, and again in September on their way south, for that bird is an uncommon species in Scandinavia.[3]

Autumn Passage.—The return movement from the north is initiated by the appearance of the White Wagtail upon our coasts from mid-August onwards. The earliest date I have is for August 15, 1894, at Barra. From this date until the middle of September it occurs in parties proceeding south at the Hebridean stations of Barra and Tiree [4] with great regularity.

The autumn passage, however, is not a prolonged one, and the latest record for the bird's occurrence in Britain, known to me, refers to a pair of adults observed in Oxfordshire on September 27, 1885.[5]

The return movement probably affects both the east and west coasts of the mainland, as the data faintly indicate. It is remarkable, however, that outside the Hebrides and the Forth area our information is of a very meagre nature, and the bird does not appear to have been observed on the east coast of England, or anywhere in Ireland in the autumn.[6]

[1] During a visit to the southern portion of Shetland in the latter half of September, 1900, I found the White Wagtail abundant on passage; not a single example of the Pied Wagtail was observed.

[2] *Birds of Shetland*, p. 81.

[3] At Heligoland the spring passage of the White Wagtail commences at mid-March, and continues until the early days of May.

[4] The Hebridean records (1892–1899) for the autumn migration of this species are as follows:—1892, September 1; 1893, August 24, 25, and 29; 1894, August 15; 1896, August 24; 1897, August 17 and September 2 and 3; 1898, August 24, September 7 and 15; 1899, August 18.

[5] Since the above was written, a single bird was noted in Southern Shetland on October 3, 1900.

[6] On the west shores of the Continent the autumn passage is regularly observed. At Heligoland it commences at mid-August, and continues until mid-October.

During our ill-fated visit to the island of Ushant, which lies immediately to the south of our extreme south-west coast, in early September 1898, Mr. Laidlaw and I saw many White Wagtails on migration. On some days as many as two hundred came under our notice, and parties of from twenty to thirty were not uncommon.

The White Wagtail is frequently noted in company with its Pied and Yellow congeners (*M. lugubris* and *M. raii*). It sometimes occurs at the lanterns of the lighthouses along with other species; thus at Skerryvore, on September 8, 1897, several were killed during a rush of 'small birds,' Wheatears (*Saxicola œnanthe*), and Pipits (*Anthus pratensis*), and their wings sent to me for identification.

It appears to me that the White Wagtails which traverse our western shores and isles are probably *en route* to and from their western summer haunts in the Færoes and Iceland. That such is the case is rendered likely not only by the routes followed in Britain, but by the dates of arrival and departure as recorded for Iceland.[1]

On the other hand, the comparatively late date on which this bird is observed in the autumn in Southern Scandinavia,[2] and the fact that its numbers are so few on our eastern seaboard, seem to indicate that the main route to north-western continental Europe does not lie on the British coasts.

There can be little doubt that the White Wagtail is still much overlooked as a British bird, or confounded with the Pied Wagtail, a species from which it was not differentiated for many years. We have thus even yet much to learn concerning its distribution in most districts of Great Britain and Ireland.

In certain areas, notably in the Hebrides, our knowledge has been considerably advanced during recent years, thanks to the excellent observations made by Dr. MacRury and Mr. Peter Anderson.

The main facts connected with the migration of the White Wagtail are :—

1. It appears on the southern coast of England during March and April, sometimes in early May.

2. During April and May—as late as the middle of the latter month—it occurs on passage on the east and west coast of Great Britain, and has been at that time occasionally observed on the north-west coast of Ireland.

3. The return passage commences with mid-August, and is over by mid-September.

4. The west coasts of Britain, and especially those of the Hebridean Islands, form the main route followed by the migrants.

5. The bird has not been observed on the east coast of Ireland at any season, nor has it been observed anywhere in Ireland during the autumn passage.

[1] In 1886 the species was first observed at Reykjanes on April 24, next on the 29th, and abundantly on May 9. Lastly, on August 3 (Gunnlaugsson, *Ornis*, 1895, p. 344). Gröndal says it is the first summer visitor, and comes in April to the Reykavik district, where one was shot as late as September 7, 1879 (*Ornis*, 1886, p. 358). The bird evidently leaves Iceland early in the autumn. Along with Mr. Backhouse, I spent the month of September 1884 in the south-east portion of the island, and we only observed this species on one occasion, namely, a family party seen on the coast on the 10th.

[2] Professor Collett (*Oversigt af Christiania Omegns ornithologiske Fauna*, p. 84) states that it arrives during the first half of April, and leaves at the end of September and first days of October. It is occasionally observed in October, and exceptionally as late as November 15.

6. It has not been observed on the east coast of England during the autumn passage.

7. Much has yet to be learned concerning the White Wagtail as a bird of passage in districts in which it is presumed to be rare or unknown.

The Climatology of Africa.—Ninth Report of a Committee consisting of Mr. E. G. RAVENSTEIN (*Chairman*), Sir JOHN KIRK, (*the late*) Mr. G. J. SYMONS, Dr. H. R. MILL, *and* Mr. H. N. DICKSON (*Secretary*). (*Drawn up by the Chairman.*)

METEOROLOGICAL returns have reached your Committee, in the course of last year, from thirty stations in Africa.

Nigeria.—We are able to publish a full year's record for Old Calabar. The observations, since September last, are being made thrice daily in accordance with our programme. We look forward with interest to the receipt of meteorological reports from Northern Nigeria, which have been promised by General F. D. Lugard, C.B., and which we hope to be able to publish in next year's report.

British Central Africa.—We regret that full reports have been received only for two stations, namely, Zomba, which is in the immediate charge of Mr. J. McClounie, the director of the scientific department, and Lauderdale, the residence of our esteemed correspondent, Mr. John W. Moir. No reports from Fort Johnston have been received, and those from thirteen other stations are more or less incomplete, owing to the occasional absence or the illness of the observers. Dr. James E. Mackay, of the London Missionary Society, whose valuable report for Kambola we published last year, has, we regret to say, given up his meteorological work, owing to ill health and the impossibility of finding a trustworthy native assistant. He writes: 'I see no way to get *regular* observations, and have, *with great regret*, resolved to give it up rather than provide unreliable and worthless reports.'

British East Africa.—Returns from ten stations have been received, including three months' observations from Nairobi, to the north of Machako's. The returns from Fort Smith, in Kikuyu, and from the neighbouring Scottish missionary station being incomplete, we defer their publication until next year, as we hope shortly to receive the returns for the missing months. No report has been received from Golbanti, on the Tana River. As an instance of the extent to which an injudicious exposure of the thermometers may affect the returns we refer to the 'Notes' on those received from Machako's. We record with regret the death of Mr. C. H. Craufurd, one of H.M.'s Sub-Commissioners, who has at all times taken a lively interest in the work of your Committee.

Uganda.—The observations on the level of Victoria Nyanza having been received only up till October, the publication of the results is deferred till next year.

Your Committee cannot conclude this report without expressing their sincere regret at the death of their late colleague, Mr. G. J. Symons, F.R.S., whose valuable counsel they have enjoyed ever since their formation in 1891.

Your Committee propose that they be reappointed for another year, to enable them to make a final report. They do not ask for a grant.

Zomba. Lat. 15·37° *S., Long.* 35·3° *E., Alt.* 2,948 *feet. Director of Observatory: J. McClounie.*

Months	Barometer (reduced to Sea-level) 7 A.M.	2 P.M.	9 P.M.	Mean Temperatures 7 A.M.	2 P.M.	9 P.M.	Mean Max.	Mean Min.	Mean	Temp. Extremes Highest	Lowest	Mean Temp. Wet Bulb 7 A.M.	2 P.M.	9 P.M.	Dew Point 7 A.M.	2 P.M.	9 P.M.	Vapour Pressure 7 A.M.	2 P.M.	9 P.M.	Relative Humidity 7 A.M.	2 P.M.	9 P.M.	Rain Amount	Days	Heaviest Fall	Thunderstorms	Cloud (0–10) 7 A.M.	2 P.M.	9 P.M.	Bright Sunshine
1899	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	p.c.	p.c.	p.c.	In.	In.	In.	Dys.				Hrs.
January . .	29·723	29·584	29·658	68·3	79·1	70·2	82·1	64·7	71·9	88·6	59·8	66·3	73·2	67·1	65·3	69·2	65·5	·623	·697	·633	90	78	85	5·84	10	3·05	4	4·8	5·5	5·2	237
February . .	·629	·550	·614	67·4	75·4	68·8	79·1	64·2	69·9	86·0	61·0	66·1	71·5	66·7	65·5	69·9	65·8	·629	·735	·632	95	83	90	11·39	24	1·50	5	7·7	8·4	9·1	50
March . .	·723	·635	·752	66·2	76·7	67·8	78·6	63·2	69·6	81·8	57·0	64·5	71·2	65·8	64·1	68·9	64·7	·592	·709	·647	92	75	90	7·06	18	2·23	2	6·2	6·6	6·3	161
April . .	·825	·713	·810	64·4	74·2	65·6	76·2	61·6	67·5	81·0	56·0	63·0	69·0	64·3	62·9	67·3	63·8	·578	·668	·592	95	79	94	9·75	18	2·75	1	6·4	6·5	7·2	145
May . .	·938	·850	·935	58·0	67·5	61·5	70·2	53·1	62·1	78·5	50·0	56·5	62·2	58·5	55·5	60·3	57·5	·444	·524	·479	91	77	91	2·70	12	1·35	0	6·0	6·6	5·6	132
June . .	30·045	·951	·988	54·3	68·2	56·8	67·9	51·5	59·0	74·0	46·0	52·4	59·4	54·6	51·1	55·0	53·3	·383	·420	·372	89	69	89	·51	5	·17	0	5·3	6·1	5·0	135
July . .	·052	·934	·990	56·6	68·6	59·7	71·1	53·8	61·1	75·0	49·0	54·8	63·0	57·3	53·6	59·8	55·8	·412	·519	·449	90	74	87	·07	3	·04	0	6·0	7·1	5·0	117
August . .	29·953	·868	·926	59·6	72·4	63·6	77·2	60·0	64·8	79·0	48·2	56·1	61·3	57·3	53·8	54·1	53·3	·417	·423	·407	82	53	70	·10	1	·10	0	3·6	3·8	3·2	223
September .	·920	·802	·911	63·6	78·1	68·2	80·8	60·2	69·5	86·0	52·2	59·7	65·8	61·5	57·5	59·3	57·8	·474	·515	·481	82	55	71	·12	1	·12	0	2·5	3·0	1·9	254
October . .	·754	·654	·714	70·3	82·5	73·1	85·5	63·7	74·8	92·0	59·0	63·8	69·4	65·3	60·5	63·5	61·1	·524	·587	·541	71	54	68	2·23	4	1·23	2	2·0	3·0	1·5	287
November .	·768	·680	·758	68·0	76·8	69·5	80·0	64·7	70·9	88·0	61·0	66·1	70·5	67·1	65·2	67·5	65·9	·622	·678	·641	91	75	88	13·40	19	2·34	6	7·4	7·3	6·4	95
December .	·737	·612	·709	68·3	76·5	69·0	80·1	64·4	70·7	85·0	60·5	66·2	71·2	66·9	65·2	68·9	66·0	·624	·709	·634	90	77	90	7·79	22	2·77	4	6·5	7·5	6·7	145
1899 . . .	29·756	·739	29·814	63·7	74·7	66·2	77·4	60·4	67·7	92·0	46·0	61·3	67·3	62·7	60·0	63·6	60·9	·527	·599	·542	87	71	84	60·96	137	3·05	24	5·4	5·9	5·3	1954
1898 . . .	·812	·684	·774	64·5	75·2	66·7	77·9	60·6	68·4	93·4	46·0	60·8	65·8	61·8	59·9	61·2	67·9	·508	·553	·507	83	65	77	62·23	144	4·67	56	5·4	5·7	4·6	2227

Zomba—continued. *Direction and Force* (0–12) *of Wind.*

Month	North 7 A.M. No.	Total Force	2 P.M. No.	Total Force	9 P.M. No.	Total Force	North-east 7 A.M. No.	Total Force	2 P.M. No.	Total Force	9 P.M. No.	Total Force	East 7 A.M. No.	Total Force	2 P.M. No.	Total Force	9 P.M. No.	Total Force	South-east 7 A.M. No.	Total Force	2 P.M. No.	Total Force	9 P.M. No.	Total Force	South 7 A.M. No.	Total Force	2 P.M. No.	Total Force	9 P.M. No.	Total Force	South-west 7 A.M. No.	Total Force	2 P.M. No.	Total Force	9 P.M. No.	Total Force	West 7 A.M. No.	Total Force	2 P.M. No.	Total Force	9 P.M. No.	Total Force	North-west 7 A.M. No.	Total Force	2 P.M. No.	Total Force	9 P.M. No.	Total Force	Calms 7 A.M.	2 P.M.	9 P.M.
1899																																																			
January . .	—	—	1	1	—	—	3	7	1	1	1	2	3	6	8	16	2	2	—	—	—	—	—	—	—	—	—	—	—	—	3	8	5	11	—	—	3	4	6	11	1	1	—	—	2	3	—	—	19	6	25
February . .	—	—	1	1	—	—	—	—	—	—	—	—	—	—	2	3	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	12	—	—	1	2	8	16	4	10	1	5	—	—	1	5	26	9	22
March . .	—	—	2	2	—	—	2	3	5	7	—	—	5	10	5	9	—	—	—	—	1	1	1	3	—	—	1	1	—	—	—	—	3	4	—	—	3	3	5	7	1	1	—	—	—	—	—	—	20	8	28
April . .	—	—	—	—	—	—	—	—	2	3	—	—	3	16	5	11	1	3	—	—	3	6	1	2	—	—	—	—	2	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	26	19	15
May . .	—	—	—	—	—	—	—	—	—	—	1	2	1	2	1	2	1	2	—	—	2	4	—	—	—	—	—	—	—	—	1	2	1	1	2	4	—	—	3	6	—	—	—	—	—	—	—	—	27	24	26
June . .	—	—	—	—	—	—	—	—	—	—	—	—	1	2	3	7	—	—	—	—	1	2	—	—	—	—	—	—	—	—	—	—	3	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	27	18	28
July . .	—	—	—	—	—	—	—	—	2	6	—	—	2	4	11	19	2	4	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	26	12	28
August . .	—	—	—	—	—	—	2	7	—	—	—	—	5	20	21	53	4	8	—	—	1	3	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	23	6	27
September .	—	—	—	—	—	—	—	—	—	—	—	—	7	16	12	35	2	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	23	17	25
October . .	—	—	—	—	—	—	—	—	—	—	—	—	19	60	22	56	5	17	1	4	3	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	3	17
November . .	—	—	—	—	—	—	—	—	—	—	—	—	6	16	9	23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	7	—	—	—	—	—	—	—	—	24	19	30
December . .	—	—	—	—	—	—	2	6	—	—	3	6	5	16	13	33	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	—	—	—	—	—	—	—	23	18	27
1899	—	—	4	4	—	—	9	23	10	17	5	10	57	168	112	267	19	47	1	4	11	27	2	5	—	—	3	3	2	4	4	10	16	34	2	4	8	11	25	48	6	12	1	5	2	3	1	5	275	159	298

Lauderdale, Mlanje. Lat. 16·03° *S., Long.* 35·6° *E., Alt.* 2,850 *feet. Observer: John W. Moir.*

Month	Mean Temperature						Temp. Extremes		Mean Temp. Wet Bulb			Dew Point			Vapour Pressure			Relative Humidity			Rain			Cloud (0–10)		
	6 A.M.	2 P.M.	9 P.M.	Max.	Min.	Mean	Highest	Lowest	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	Amount	Days	Highest Fall	7 A.M.	2 P.M.	9 P.M.
1899	°	°	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	p.c.	p.c.	p.c.	In.	No.	In.			
January	68·2	80·5	71·8	84·3	66·2	73·5	99·8	61·6	64·5	72·2	66·1	64·2	68·6	63·4	·599	·703	·583	87	67	75	9·31	14	3·69	3·6	7·2	4·3
February	69·0	76·1	71·0	78·8	66·9	72·0	87·6	61·7	63·2	72·4	68·0	60·2	71·0	66·7	·521	·757	·654	74	85	87	21·94	26	4·46	9·1	9·0	9·1
March	66·6	77·2[1]	69·5	73·7	64·3	71·1	82·9	59·5	64·2	70·6[1]	66·6	63·0	67·9[1]	65·2	·575	·681[1]	·622	88	72[1]	86	21·91	18	8·56	4·5	7·0[1]	4·1
April	64·3	73·8	68·1	74·3	63·2	68·7	80·0	57·9	62·6	69·6	65·8	62·3	67·8	64·8	·560	·680	·611	93	82	89	19·16	25	2·85	4·4	7·5	6·5
May	58·7	68·7	62·3	69·4	56·7	63·2	79·0	49·2	55·6	63·4	59·0	54·3	60·7	57·1	·421	·530	·466	85	76	83	7·05	22	1·21	4·9	6·7	5·8
June	55·0	64·8	58·6	63·9	53·5	59·5	72·0	50·3	52·9	58·2	55·4	51·4	54·2	53·3	·379	·419	·406	88	69	83	5·15	17	1·48	4·7	6·4	4·9
July	57·3	66·5	61·8	71·5	55·1	61·9	79·5	53·0	54·2	59·7	57·3	52·2	55·7	54·5	·389	·444	·425	83	68	77	4·49	8	1·48	3·8	7·9	4·7
August	58·3	72·8	65·3	79·1	57·5	65·5	80·1	53·0	55·3	62·5	58·4	53·0	56·9	54·2	·401	·462	·419	82	57	67	0·76	4	0·65	1·9	6·4	1·6
September	64·2	77·7[1]	69·0[1]	83·4	59·6	70·3	89·9	54·0	59·1	64·0[1]	60·3[1]	56·1	56·6[1]	55·3[1]	·450	·458[1]	·436[1]	75	48[1]	62[1]	0·77	1	0·77	2·5	7·0	1·0
October	68·0	83·1[1]	73·5	85·5	64·5	74·9	90·3	57·5	63·9	70·6[1]	64·7	61·8	65·3[1]	60·2	·552	·622[1]	·522	80	56[1]	63	6·87	5	2·57	2·1	5·9	2·2
November	67·1	76·3[1]	72·2	79·4	64·3	71·8	89·1	61·0	65·1	71·4[1]	66·8	64·1	69·4	64·4	·597	·719[1]	·603	90	79[1]	77	17·67	22	2·27	4·0	9·0	5·0
December	69·2	73·9	71·0	78·8	65·7	71·4	94·6	59·8	65·8	73·1	66·7	64·7	72·8	64·7	·610	·805	·611	86	96	80	13·06	20	3·02	4·8	7·1	5·4
Year 1899	63·8	74·5	67·8	76·5	61·6	68·7	99·8	49·2	60·5	67·3	62·9	58·7	64·0	60·3	·504	·607	·529	84	71	77	128·14	182	8·56	4·2	7·2	4·5
,, 1898	63·8	75·7	68·9	78·0	62·8	69·5	95·0	51·2	61·1	68·6	63·8	59·6	65·3	61·2	·518	·643	·547	87	72	77	158·87	207	9·67	4·9	5·4	4·1

[1] Number of observations too small for a trustworthy mean.

HAIL.—A heavy fall at 4 P.M. on November 27, 1899.

Lauderdale—continued. *Direction and Force* (0–12) *of Wind.*

Month	North						North-east						East					
	6 A.M.		2 P.M.		9 P.M.		6 A.M.		2 P.M.		9 P.M.		6 A.M.		2 P.M.		9 P.M.	
	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force
1899																		
January	13	22	4	7	14	26	—	—	—	—	—	—	1	2	—	—	1	2
February	12	15	2	2	12	26	3	3	—	—	1	2	—	—	1	2	1	1
March	1	1	—	—	1	1	7	7	—	—	1	2	11	18	—	—	17	41
April	7	12	—	—	—	—	2	2	—	—	—	—	1	2	2	3	6	10
May	5	11	2	3	3	8	1	2	1	1	1	2	3	7	2	2	4	12
June	10	19	—	—	2	5	—	—	1	1	—	—	1	5	1	2	—	—
July	17	31	1	2	2	3	3	3	—	—	—	—	—	—	—	—	5	13
August	26	52	12	23	9	20	—	—	—	—	—	—	—	—	—	—	2	6
September	10	15	1	2	2	4	3	4	—	—	1	4	4	5	1	4	3	6
October	12	16	2	4	6	9	2	2	—	—	2	7	2	3	1	3	7	21
November	12	14	—	—	3	3	1	1	—	—	3	3	5	8	—	—	9	28
December	9	17	4	9	11	22	—	—	1	2	1	2	1	2	2	5	2	5
1899	134	225	28	52	65	127	22	24	3	4	10	22	29	52	10	21	57	145
1898	13	13	15	17	13	17	4	4	2	2	12	17	21	37	21	29	35	67

Month	South-east						South						South-west					
	6 A.M.		2 P.M.		9 P.M.		6 A.M.		2 P.M.		9 P.M.		6 A.M.		2 P.M.		9 P.M.	
	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force
1899																		
January	9	19	7	16	8	16	—	—	2	4	—	—	—	—	1	3	—	—
February	4	5	8	15	6	10	—	—	—	—	2	2	—	—	—	—	—	—
March	5	9	3	4	10	19	—	—	—	—	—	—	—	—	—	—	—	—
April	12	24	6	14	17	42	4	7	5	10	3	7	—	—	—	—	—	—
May	20	61	19	46	18	52	—	—	—	—	—	—	—	—	—	—	—	—
June	17	44	21	58	27	82	1	3	6	16	1	2	—	—	—	—	—	—
July	7	29	8	23	19	56	—	—	—	—	—	—	—	—	—	—	—	—
August	4	10	7	25	19	75	—	—	4	10	—	—	—	—	—	—	—	—
September	2	4	3	6	3	14	—	—	1	2	—	—	—	—	—	—	—	—
October	4	8	2	4	4	16	—	—	1	2	1	3	—	—	—	—	—	—
November	4	12	4	9	7	25	4	4	—	—	—	—	—	—	1	2	—	—
December	6	16	10	25	14	47	1	4	6	16	1	1	—	—	2	4	—	—
1899	94	241	98	245	152	454	10	18	25	60	8	15	—	—	4	9	—	—
1898	66	102	88	108	113	178	19	18	25	32	14	18	1	4	—	—	—	—

Month	West						North-west						Calms		
	6 A.M.		2 P.M.		9 P.M.		6 A.M.		2 P.M.		9 P.M.		6 A.M.	2 P.M.	9 P.M.
	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	No.	No.
1899															
January	1	1	1	1	—	—	1	1	3	5	—	—	—	1	2
February	3	3	2	2	—	—	—	—	4	13	—	—	4	1	4
March	2	2	—	—	—	—	3	4	—	—	—	—	—	—	—
April	—	—	1	2	—	—	—	—	—	—	—	—	4	5	4
May	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—
June	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	1	2	1	3	1	2	—	1	1
August	—	—	—	—	—	—	—	—	1	2	—	—	—	1	1
September	1	1	—	—	—	—	1	1	—	—	—	—	—	—	1
October	2	2	—	—	3	5	—	—	1	2	2	2	2	—	1
November	—	—	—	—	—	—	—	—	—	—	2	2	1	—	—
December	—	—	—	—	—	—	1	2	1	2	—	—	10	3	2
1899	10	10	4	5	3	5	7	10	11	27	5	6	21	14	16
1898	—	—	4	8	1	1	9	12	8	6	5	6	214	157	160

Zomba.

All observations have been corrected for instrumental errors, with the exception of the readings of the barometer, the Kew certificate for which does not extend beyond 27·5 in., the correction for 28·00 in. and 27·5 in. amounting to 0·006 in. This amount might fairly be deducted from the entries in the table.

Mr. McClounie has reduced the barometrical readings to 32° F., to mean gravity at lat. 45° and to sea-level, on the assumption that the cistern is 2,948 feet above sea-level. This assumed altitude yields a mean pressure of 29·763 in. (January, 29·639 in.; July, 30·311 in. for 1898 and 1899.) The corresponding values, according to Buchan's Chart in Bartholomew's 'Physical Atlas,' are 29·96, 29·80, and 30·10 in.

Force of Wind.

The total wind force was 711 (mean 0·69) as compared with 1,058 (mean 98) in 1898. The number of calms was 732 (in 1898 667). Out of 300 winds recorded, as many as 226 came from the E., N.E., and S.E. (total force 568; mean force 2·51), as compared with 65 from the W., S.W., and N.W. (total force 132; mean 2·03).

The greater calmness of the atmosphere, the increased cloudiness, and the decrease in the hours of sunshine are accountable for the greater humidity in 1899, which was 81 p.c., as compared with 75 p.c. in 1898.

Wind and Temperature.

A combination of these two elements yields the following results:—

Direction of wind 1899	Year		Rainy Season [1]		Dry Season	
	No. of Observations	Mean Temp.	No. of Observations	Mean Temp.	No. of Observations	Mean Temp.
North and North-east	210	73°	86	75°	124	72
West and South-west	60	71	49	73	11	64
Calms .	718	66	358	70	360	63

[1] Rainy season: November to April. Dry season: May to October. The N.E. descends from Mount Zomba.

Lauderdale.

The observations are published as recorded, but there is no reason to believe that the instruments now in use are out of order.

Force of Wind.

The total wind force was 1,767, as compared with 695 in 1895; but whilst in the latter year 'calms' were entered 531 times, there were only 51 such entries in 1899.

Out of 799 'winds' recorded, as many as 344 came from the S.E. (total force 940, mean 2·7), and 227 from the N. (total force 404, mean 1·8). Of all winds that from the S.E., which enters through the gap of the Kilimani road, is the strongest and also the coolest. See Report for 1897, Kilimani.

Wind and Temperature.

A combination of the two elements yields the following results:—

Direction of wind 1899	Year		Rainy Season [1]		Dry Season [1]	
	No. of Observations	Mean Temp.	No. of Observations	Mean Temp.	No. of Observations	Mean Temp.
N.	227	67°	105	71°	122	63°
N.E.	35	67	20	69	15	64
E.	96	70	60	69	36	70
S.E.	344	66	140	71	204	62
S.	43	69	28	68	15	70
S.W.	5	77	4	75	1	85
W.	17	71	10	73	7	68
N.W.	22	73	15	76	7	67
Calm	51	72	41	72	10	68

[1] Rainy Season: Nov., Dec., Jan. to April. Dry Season: May to October.

Port Herald, Lat. 16·67°, *Long.* 35·25°, *Alt.* 100 *feet. Observer: H. J. Morris.*

Month and No. of Days	Mean Temp.				Rain		
	7 A.M.	2 P.M.	9 P M	Mean	Amount	Days	Heaviest Fall
1899	°	°	°	°	In.	No.	In.
January (24 days)	85·2	100·5	85·4	89·1	2·73	6	1·05
February (14) .	77·4	92·0	10·0	82·3	17·72	13	7·60
March (20) . .	80·5	92·1	80·1	83·2	3·80	6	1·70
April (25) . .	77·9	89·0	71·0	77·2	3·60	7	2·50
May (14) . .	60·9	78·2	71·3	71·9	1·50	5	·50
June (27) . .	60·2	71·3	64·1	64·9	1·50	7	·50
July (22) . .	67·4	81 8	71·4	73·0	·50	2	·30
August (14) .	68·1	85·0	74·0	75·3	—	—	—

Chiromo, Lat. 16·52°, *Long.* 35·17°, *Alt.* 125 *feet. Observer: Lewis C. Way.*

Month	Mean Temp.				Rain			Bright Sunshine
	7 A.M.	2 P.M.	9 P.M.	Mean	Amount	Days	Heaviest Fall	
1899	°	°	°	°	In.	No.	In.	Hrs.
January . .	79·3	98·4	79·8	84·3	1·70	6	·45	332
February . .	77·3	89·1	77·4	80·3	15·83	22	5·97	82
March. . .	77·9	94·7	76·7	81·5	3·24	13	·83	293
April . . .	75·2	95·7	75·4	80·4	1·62	8	·48	196
May . . .	68·2	86·1	66·2	71·7	·59	6	·19	175
June . . .	64·6	84·3	63·1	68·8	1·30	10	·40	126
July . . .	65·1	88·1	66·3	73·9	·31	5	·11	223

The temperature in the shade rose to 100° on 18 days in January, 5 in February, and 5 in March.

Mangoche, 14·5° *S.,* 35·7° *E.,* 4,975 *feet. Observer: C. Percival.*

Month	Mean Temp.			Rain	
	7 A.M.	2 P.M.	9 P.M.	Amount	Days
1899	°	°	°	In.	
May . .	54·4	61·1	55·9	—	—
June . .	52·5	60·0	54·9	0·17	3
July . .	53·7	62·5	58·6	·00	0
September .	62·5	74·4	67·0	?	1
November .	64·2	75·7	70·2	3·06	2 ?
December .	64·9	72·1	65·1	11·73	11 ?

These values must be looked upon as merely approximate, the hours of observation not having been strictly adhered to.

Fragmentary Rainfall Observations, Nyasaland, 1899.

Blantyre. Nov. 6·38 in.; December, 8·82 in.

Fort Anderson (Mlanje). January, 6·11 in.; February, 20·87 in.; March, 19·84 in.; June, 3·47 in.; July, 8·32 in.

Fort Lister (Mlanje). April, 2·5 in.; May, 7·00 in.

Livonde (Upper Shiré). January, 4·55 in.; February, 19·74 in.; March, 6·72 in.; December, 6·01 in.

Deep Bay. Jan. 1·99 in.; February, 2·22 in.

Mkoma, Angoni Land (11·6° S., 34·6° E.), 3,700 feet. February, 11·40 in.

Kambola, Tanganyika. January, 9·61 in.; February, 5·34 in.

Nkawa Estate, Cholo. *Lat. 16·05° S., Long. 35·11° E., Alt. 3,400 feet. Observer: Geo. Adamson.*

Month	Mean Temp. 7 A.M.	Mean Temp. 2 P.M.	Mean Temp. 9 P.M.	Mean Temp. Mean	Rain Amount	Rain Days	Rain Heaviest Fall	Thunderstorms	Dew	Cloud (0–10) 7 A.M.	Cloud 2 P.M.	Cloud 9 P.M.	Bright Sunshine	Mist
1899	°	°	°	°	In.	No.	In.	No.	Days				Hrs.	Days
January	68·9	79·1	69·0	71·5	3·32	9	1·19	6	16	2·5	4·7	3·9	214	—
February	66·5	76·9	67·0	69·3	16·32	24	3·73	11	1	7·2	7·3	7·1	58	—
March	64·7	77·0	66·7	68·5	9·37	14	2·32	5	12	4·0	6·0	4·6	140	5
April	62·4	73·5	64·8	66·4	6·15	13	1·33	1	2	7·0	5·0	5·0	101	11
May	53·6	69·6	57·6	59·6	4·63	11	1·02	—	—	6·0	5·0	5·0	106	9
June	51·4	68·4	53·6	56·7	3·78	11	·98	—	—	8·0	6·3	4·0	92	18
July	52·5	71·7	57·2	59·7	·98	2	·90	—	—	4·1	4·0	4·5	133	4
August	57·6	74·1	60·1	62·9	·34	2	·20	—	6	2·6	3·0	2·0	222	1
September	60·4	79·5	65·6	67·8	·00	0	·00	—	—	2·7	2·2	0·6	268	5
October	66·3	82·3	69·8	72·1	2·16	3	1·04	3	—	2·0	3·3	2·3	239	—
November	—	—	—	—	2·30	7	—	—	—	—	—	—	230	—
December	67·4	77·5	67·9	71·2	4·66	10	1·45	7	—	3·8	6·2	4·9	157	—
1899 (11 months)	61·1	75·4	63·6	65·9	51·71	99	3·73	33	37	4·4	4·8	4·0	1730	53
1898	62·3	77·0	64·8	67·2	75·06	103	4·27	41	—	4·4	5·1	3·8	1976	—

All observations have been corrected for instrumental error.

The total estimated force of the wind for 11 months was 2,359 or a mean in ·972 observations of 2·4, viz., 2·4 at 7 A.M., 3·1 at 2 P.M., and 1·8 at 9 P.M. The predominant wind is the S. (349 observations out of a total of 972, or 34·9 p.c.), but the N.E. blows strongest (mean force 3·4, that of the S. being only 2·5).

Nkata, Nyasa. *Lat. 11·60 S., Long. 34·30° E., Alt. 1,650 feet. Observers: C. A. Cardew and C. Knipey.*

Month and No. of Days	Mean Temp. 7 A.M.	Mean Temp. 2 P.M.	Mean Temp. 9 P.M.	Mean Temp. Mean	Rain Amount	Rain Days	Rain Heaviest Fall	Cloud (0–10) 7 A.M.	Cloud 2 P.M.	Cloud 9 P.M.	Bright Sunshine
1899	°	°	°	°	In.	No.	In.				Hrs.
January (22)	71·2	82·8	74·4	75·7	3·03	11	0·75	8·0	6·2	5·3	200
February (23)	72·4	84·1	75·6	76·9	4·44	15	1·00	8·7	7·1	7·4	150
March (31)	71·3	83·2	74·4	75·8	8·73	17	1·95	5·8	4·1	4·0	152
April (30)	72·3	83·3	72·8	75·3	13·83	13	2·22	5·7	3·2	4·2	147
June (28)	61·2	73·0	63·0	65·0	5·15	6	1·40	5·0	3·3	1·9	195
July (24)	62·4	74·2	63·2	65·7	5·88	4	3·31	5·0	3·8	2·5	154
September (5)	69·5	84·0	71·8	74·3	0·00	0	—	—	—	—	—
October (29)	76·9	86·0	76·0	78·7	0·35	1	0·35	—	—	—	—
December (28)	70·8	81·2	74·5	75·2	11·16	20	3·61	8·9	5·7	7·5	170

Earthquake.—A slight shock was felt on April 29 at 5.14 A.M.

Waterspout, observed at 7.15 A.M., June 30, on lake, travelling from S. to N.

The observations have been corrected for instrumental error. The rain appears to have been permitted to accumulate in the rain-gauge, and the number of rainy days may therefore be slightly in excess of what is stated in the table. An estimate of the sunshine has been made for days on which the observer was absent.

Nkawa Estate, Cholo—continued. *Direction and Force (0–12) of Wind.*

Month	North 7 A.M. No.	North 7 A.M. Force	North 2 P.M. No.	North 2 P.M. Force	North 9 P.M. No.	North 9 P.M. Force	North-east 7 A.M. No.	North-east 7 A.M. Force	North-east 2 P.M. No.	North-east 2 P.M. Force	North-east 9 P.M. No.	North-east 9 P.M. Force	East 7 A.M. No.	East 7 A.M. Force	East 2 P.M. No.	East 2 P.M. Force	East 9 P.M. No.	East 9 P.M. Force
1899																		
January	3	6	3	7	—	—	10	35	7	16	1	11	2	2	1	4	—	—
February	16	32	7	31	11	31	2	7	3	11	—	—	—	—	1	3	—	—
March	2	8	4	7	3	5	2	5	1	3	1	2	—	—	—	—	—	—
April	1	3	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	1	2	1	1	—	—	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—	1	3	—	—	—	—	3	10	—	—
July	—	—	1	3	—	—	3	8	4	11	2	5	4	11	2	5	—	—
August	3	10	5	18	5	6	13	40	5	18	5	6	2	7	2	7	—	—
September	8	34	4	16	1	1	12	51	3	14	1	5	—	—	1	4	—	—
October	17	72	15	73	12	37	10	63	7	22	8	26	—	—	—	—	—	—
November	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
December	6	13	7	25	7	13	12	41	5	16	8	14	—	—	3	12	1	3
1899 (11 months)	56	178	47	181	39	93	65	252	37	115	26	69	8	20	13	45	1	3

Month	South-east 7 A.M. No.	South-east 7 A.M. Force	South-east 2 P.M. No.	South-east 2 P.M. Force	South-east 9 P.M. No.	South-east 9 P.M. Force	South 7 A.M. No.	South 7 A.M. Force	South 2 P.M. No.	South 2 P.M. Force	South 9 P.M. No.	South 9 P.M. Force	South-west 7 A.M. No.	South-west 7 A.M. Force	South-west 2 P.M. No.	South-west 2 P.M. Force	South-west 9 P.M. No.	South-west 9 P.M. Force
1899																		
January	6	11	7	18	4	10	7	8	12	35	8	4	—	—	1	3	—	—
February	1	2	2	6	—	—	—	—	3	4	3	8	1	2	2	5	7	9
March	6	14	5	13	3	5	10	10	19	56	14	35	—	—	2	9	—	—
April	6	12	7	21	4	9	8	16	21	61	15	31	—	—	1	4	—	—
May	4	11	8	23	1	3	13	36	21	55	22	51	—	—	—	—	—	—
June	—	—	8	24	1	4	20	50	18	53	10	20	—	—	—	—	—	—
July	10	27	13	45	4	12	7	22	11	34	4	15	—	—	—	—	—	—
August	3	8	9	30	5	7	6	14	10	26	12	26	—	—	1	3	—	—
September	2	8	7	24	5	13	7	21	14	48	16	34	—	—	1	3	2	2
October	2	7	4	15	1	5	2	5	5	14	10	27	—	—	—	—	—	—
November	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
December	4	10	5	16	3	6	6	17	6	22	9	17	—	—	2	7	—	—
1899 (11 months)	44	110	75	235	31	74	86	199	140	407	123	268	1	2	10	34	9	11

Month	West 7 A.M. No.	West 7 A.M. Force	West 2 P.M. No.	West 2 P.M. Force	West 9 P.M. No.	West 9 P.M. Force	North-west 7 A.M. No.	North-west 7 A.M. Force	North-west 2 P.M. No.	North-west 2 P.M. Force	North-west 9 P.M. No.	North-west 9 P.M. Force	Calm 7 A.M. No.	Calm 2 P.M. No.	Calm 9 P.M. No.
1899															
January	—	—	—	—	—	—	—	—	—	—	—	—	3	—	10
February	1	2	2	7	1	4	4	12	8	28	2	10	3	—	4
March	—	—	—	—	—	—	—	—	—	—	—	—	11	—	—
April	—	—	—	—	—	—	—	—	—	—	—	—	15	—	11
May	—	—	—	—	—	—	—	—	—	—	—	—	13	1	8
June	—	—	—	—	—	—	—	—	—	—	—	—	10	—	19
July	—	—	—	—	—	—	—	—	—	—	—	—	7	—	21
August	—	—	—	—	—	—	—	—	—	—	—	—	3	—	2
September	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
October	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
November	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
December	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1899 (11 months)	1	2	2	7	1	4	4	12	8	28	2	10	65	1	77

Mombasa. 4·07° *S.*, 39·7° *E.*, 60 *feet.*
Observer: the late C. R. Craufurd.

Month	Pressure of Atmosphere 9 A.M.	Mean Temperatures					Temperature Extremes		Daily Range	Humidity, 9 A.M.			Rain		
		Dry 9 A.M.	Wet 9 A.M.	Mean Max.	Mean Min.	Mean 9 A.M.	Highest	Lowest		Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest fall in 24 hours
1899	In.	°	°	°	°	°	°	°	°	°	In.	P.c.	In.	No.	In.
January	29·851	82·9	79·7	86·4	80·3	83·4	88	78	6·1	78·2	·962	85	0·03	1	·03
February	·838	84·0	79·6	87·2	80·4	83·8	89	78	6·8	·4	·961	82	·00	0	—
March	·847	83·9	81·2	87·5	81·7	84·6	89	77	5·8	80·3	1·033	89	3·45	8	·87
April	·844	85·4	82·9	88·7	83·1	85·7	90	84·5	5·6	82·1	1·096	90	1·65	4	1·11
May	·891	78·9	77·4	83·8	75·5	79·6	89	74	8·3	76·7	·917	92	14·86	15	2·78
June	·986	79·0	77·2	83·4	75·2	79·3	84	74	8·2	76·5	·912	92	·82	4	·71
July	30·010	77·1	75·1	83·0	73·3	78·1	83·5	73	9·7	74·4	·847	91	4·92	14	1·55
August	·004	77·8	76·7	83·0	73·5	78·2	83	73	9·5	76·3	·905	95	3·11	11	1·01
September	·012	79·9	78·6	85·4	76·8	83·1	86	76	8·6	78·2	·962	94	1·48	10	·61
October	29·938	82·5	80·1	86·4	78·0	82·2	88	77	8·4	79·3	·999	90	·33	7	·15
November	·881	84·7	83·0	87·2	82·5	84·9	88	81	4·7	82·5	1·108	92	2·01	10	·69
December	·837	84·8	82·5	88·5	82·4	85·4	89	81	6·1	78·8	·984	88	2·50	10	1·05
Year 1899	29·911	81·7	79·4	85·9	78·6	82·3	90·0	73·0	7·3	78·5	·974	90	35·16	94	2·78
„ 1898	·906	80·3	75·6	82·9	75·8	79·3	89·0	70·0	7·1	73·8	·832	81	63·24	94	4·1

All readings have been corrected for instrumental error, excepting those of the barometer (see Report for 1898).

The barometrical observations have been reduced to 32° F. and to standard gravity in Lat. 45°, but not to the sea-level.

The mean temperature is assumed to be the mean of all max. and min., and is therefore too high.

The rainfall in 1899 was the highest experienced since 1895. The average, 1891–99, has been 47·36 in. The relative humidity in 1899 would appear to have been about 9 p.c. in excess of that of previous years, if the wet bulb readings can be trusted.

Shimoni (Wanga). *Lat.* 4·63° *S.*, *Long.* 39·35° *E.*
Observers: M. G. Carvalho, A. C. Hollis, and E. J. H. Russell.

Month	Atmospheric Pressure		Mean Temp. 9 A.M.		Humidity, 9 A.M.			Rain			Prevailing Wind at 9 A.M.								
	9 A.M.	3 P.M.	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest fall in 24 hours	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Cal.
1899	In.	In.	°	°	°	In.	P.c.	In.	No.	In.									
January	29·849	29·801	83·8	80·8	79·8	1·016	88	0·32	3	0·22	3	16	12	—	—	—	—	—	—
February	·830	·777	84·1	81·6	80·8	1·050	89	·00	0	—	2	20	6	—	—	—	—	—	—
March	·861	·800	83·5	81·5	80·9	1·051	92	1·52	10	·35	2	—	14	—	14	—	1	—	—
April	·903	·850	80·8	79·1	78·5	·973	92	7·53	14	3·00	—	—	—	—	30	—	—	—	—
May	·912	·872	76·9	75·2	74·5	·852	92	27·05	19	4·60	—	—	—	—	29	2	—	—	—
June	30·031	·923	76·0	74·1	73·4	·820	92	2·44	8	·64	—	—	—	—	30	—	—	—	—
July	·028	·995	75·0	74·0	73·6	·827	95	7·71	13	1·50	—	—	—	—	31	—	—	—	—
August	·014	·971	76·0	75·0	74·6	·855	95	1·48	7	·40	—	—	—	1	30	—	—	—	—
September	·029	·969	76·7	75·1	74·5	852	93	·41	3	·21	—	—	—	30	—	—	—	—	—
October	·005	·878	77·7	76·2	75·7	·886	94	·99	3	·50	—	—	—	28	3	—	—	—	—
November	29·959	·875	81·0	78·7	77·9	·954	91	·75	3	·53	—	—	7	17	1	—	4	—	—
December	·896	·835	83·2	81·1	80·3	1·03 3	91	2·31	8	·50	—	3	18	3	3	—	4	—	—
Year 1899	29·943	29·879	79·6	77·7	77·0	·927	92	52·51	91	4·60	7	39	57	79	171	2	9	—	—
„ 1898	·901	—	80·7	79·1	78·5	·974	93	27·30	85	2·80	10	12	69	25	72	138	27	12	—

All readings, excepting those of the 'dry' bulb, have been corrected for instrumental error (see Report for 1898, p. 606). It seems there is now a second 'dry bulb' thermometer, in addition to that attached to the barometer. The readings of the two are in most instances identical, the mean for the year of the attached thermometer being the same as that of the 'dry' bulb inserted in the table, viz., 77·7° F.

Nairobi, 1·3° *S.*, 36·95° *E.*, *Alt.* 5,450 *feet.*

Rainfall in 1899:—October, 4·62 in., on 5 days.
November, 2·30 in., on 10 days.
December, 2·34 in., on 4 days.

Machako's, Lat. 1·52° S., Long. 37·30° E., 5,400 feet. *Observer: W. Maclellan Wilson.*

Month	Mean Temp. 9 A.M. Dry	Mean Temp. 9 A.M. Wet	Humidity 9 A.M. Dew Point	Humidity 9 A.M. Vapour Pressure	Humidity 9 A.M. Relative Humidity	Rain Amount	Rain Days	Rain Heaviest fall in 24 hours	Cloud (0–10)
1899	°	°	°	In.	P.c.	In.	No.	In.	
January	67·3	57·5	51·8	·385	56	0·20	1	·20	2·5
February	68·9	60·1	55·5	·440	61	0·30	1	·30	3·0
March	68·5	59·4	54·5	·424	60	1·03	5	·62	3·9
April	67·0	61·4	58·6	·492	74	5·69	14	1·70	5·5
May	66·3	60·4	57·4	·471	72	2·17	9	1·12	5·9
June	61·4	54·4	50·0	·360	65	·00	0	—	3·6
July	59·8	54·4	51·0	·374	73	·26	5	·13	7·3
August	60·1	54·9	51·8	·384	74	·13	3	·06	8·0
September	63·6	58·1	55·0	·433	74	·00	0	—	5·4
October	66·2	60·7	57·9	·480	75	4·78	12	1·99	4·2
November	66·1	62·8	61·2	·540	84	4·68	15	1·31	5·9
December	66·5	61·6	59·2	·503	71	2·58	13	1·17	3·0
Year 1899	65·1	58·8	55·3	·441	70	21·82	78	1·99	4·9
„ 1898	64·9	59·1	56·5	·456	74	24·32	72	2·37	—

Machako's.—In September a new set of instruments came into use. The old thermometer had been set up on a board hanging on the wall of a stone house on the verandah. The new instruments were placed (*continued beside table below*)

Kisimayu. Lat. 0·37° S., Long. 43·55° E. *Observers: Wallace Blake, R. G. Farrant, and J. W. P. McClellan.*

Months	Atmospheric Pressure 9 A.M.	Atmospheric Pressure 3 P.M.	Mean Temp. 9 A.M.	Mean Temp. 3 P.M.	Rain Amount	Rain Days	Rain Heaviest fall in 24 hours
1899	In.	In.	°	°	In.	No.	In.
January	29·854	29·776	80·5	81·6	0·00	—	—
February	·872	·796	80·7	81·5	·00	—	—
March	·867	·763	81·4	82·4	·00	—	—
April	·852	·739	84·3	85·5	·25	2	·15
May	·865	·769	81·8	82·1	2·92	5	1·12
June	·950	·900	78·9	79·4	5·27	13	4·12
July	30·031	·956	78·3	79·2	2·15	10	·35
August	·003	·916	78·6	79·3	1·55	5	·50
September	·028	·930	79·2	79·9	·25	1	·25
October	29·941	·852	81·9	81·8	·00	—	—
November	·895	—	83·9	—	·00	—	—
December	·950	—	83·9	—	·01	1	—
Year 1899	29·925	—	81·1	—	12·40	37	4·12
„ 1898	29·885	—	80·8	—	10·91	30	3·41

The barometrical readings have been reduced to standard temperature of 32° F. and standard gravity in lat. 45°, but not to sea-level. The results should be received with some hesitation, as the readings of the attached thermometer are not given by the observer.

Lamu. Lat. 2·27° S., Long. 40·9° E. *Observer: A. S. Rogers.*

Month	Mean Temp. 9 A.M. Dry	Mean Temp. 9 A.M. Wet	Humidity 9 A.M. Dew Point	Humidity 9 A.M. Vapour Pressure	Humidity 9 A.M. Relative Humidity	Rain Amount	Rain Days	Rain Heaviest fall in 24 hours
1899	°	°	°	In.	P.c.	In.	No.	In.
January	83·1	80·1	79·1	·992	88	0·00	—	—
February	82·5	79·5	78·5	·972	88	·00	—	—
March	83·2	79·9	78·8	·983	86	·00	—	—
April	84·7	80·6	79·3	·997	84	·40	2	·30
May	81·7	78·8	77·8	·950	88	15·66	15	4·50
June	79·6	77·4	76·6	·914	91	1·93	4	·60
July	78·7	76·7	76·0	·895	92	2·59	6	1·10
August	78·6	76·0	75·1	·868	89	1·00	2	·90
September	80·8	78·8	78·1	·960	92	—[1]	—[1]	—[1]
October	83·6	81·1	80·3	1·032	89	—	—	—
November	84·9	82·1	81·2	1·063	89	—	—	—
December	85·2	80·8	79·4	1·001	83	—	—	—
Year 1899	82·2	79·3	78·4	·970	88	—	—	—
„ 1898	82·0	78·2	76·8	922	84	12·39	31	2·14

All observations are corrected for instrumental errors.

[1] *Rainfall.*—No observations after August, the measuring glass having been accidentally broken.

Machako's (continued)

in a grass-shed in a favourable situation, with the side walls open, and at some distance from houses or trees. Both sets were read simultaneously during September, and it was then found that the following corrections have to be applied to all readings recorded up to the beginning of September 1899, viz. *minus* 1·8° to the dry bulb and *minus* 2·9° to the wet bulb. These corrections have been applied above.

In computing the dew point &c. a mean pressure of 24·5 inches has been assumed.

The force of the wind was estimated according to the following scale:—

	Miles per hour		Miles per hour
0. —	0	4. Fresh	26–30
1. Calm	0–5	5. Strong	31–40
2. Light	6–15	6. Gale	40 and upwards
3. Moderate	16–25		

The total number of observations was 360, the mean force of all winds was 1·7; the strongest winds were N. and N.E. (mean force 2·9 and 2·2); the mean temperature was 65·2° F.; the warmest wind N.E. (67·9°), the coolest S.W. (60·7°).

Slight earthquake shocks were experienced on July 18 at 1.45 P.M., and on July 19 at 9.30 A.M.

Machako's—continued. *Frequency, Force* (0–6), *and Temperature of each Wind at* 9 A.M.

Month, 9 A.M.	North No. of Obs.	North Total Force	North Mean Temp.	North-east No. of Obs.	North-east Total Force	North-east Mean Temp.	East No. of Obs.	East Total Force	East Mean Temp.	South-east No. of Obs.	South-east Total Force	South-east Mean Temp.	South No. of Obs.	South Total Force	South Mean Temp.	South-west No. of Obs.	South-west Total Force	South-west Mean Temp.	West No. of Obs.	West Total Force	West Mean Temp.	North-west No. of Obs.	North-west Total Force	North-west Mean Temp.	Calms No. of Obs.	Calms Mean Temp.
January	2·5	17·5	64·8	8·5	20·5	67·1	10	20·5	68·6	7	13	67·4	3	6·5	68·0	—	—	—	—	—	—	—	—	—	—	—
February	1	2	69·0	5·5	14·5	70·7	10	21·5	68·7	6	13	67·7	5·5	11	68·5	—	—	—	—	—	—	—	—	—	—	—
March	1·5	4·5	67·3	3·0	8	70·7	13·5	37·5	67·2	7	13·5	69·7	4	7·5	68·5	—	—	—	—	—	—	—	—	—	1	69·0
April	—	—	—	—	—	—	9	22	67·3	13	25	67·1	5	7	66·6	—	—	—	1	2	68·0	—	—	—	2	65·0
May	—	—	—	—	—	—	1·5	5	63·3	11·5	20	67·3	5	6	66·4	1	1	60·0	3	4	65·3	—	—	—	8	64·6
June	0·5	0·5	68·0	0·5	0·5	64·0	2·5	3·5	62·8	12·5	20	61·4	5	5·5	63·0	2	2	60·5	—	—	—	—	—	—	6	59·8
July	—	—	—	—	—	—	3·5	8	62·0	22·5	39	59·5	4	6	59·8	—	—	—	—	—	—	—	—	—	1	61·0
August	—	—	—	—	—	—	—	—	—	21	39·5	60·1	4	7·5	60·0	1	1·5	61·3	1	1·5	61·3	—	—	—	4	59·0
September	—	—	—	—	—	—	3 5	6·5	62·6	16·5	25·5	63·1	1·5	2·5	64·7	0·5	0·5	66·0	0·5	0·5	64·0	0·5	0·5	63·4	7	63·3
October	1	1	67·0	1	2	65·0	5·5	7	65·8	18	33	66·3	3·5	6	65·7	—	—	—	—	—	—	—	—	—	1	66·0
November	—	—	—	5·0	8	65·8	11	15·5	65·5	11	16	67·1	2	2·5	66·5	—	—	—	—	—	—	—	—	—	1	66·0
December	4·5	6	65·3	6·5	11·5	67·2	8	11	65·7	5	8·5	66·8	2·5	3·5	67·6	—	—	—	1	1	68·0	—	9·5	64·0	2	68·0
Year	11	31·5	66·0	30	65·0	67·9	78	158	65·1	152	266	63·7	45	71·5	65·4	4·5	5	60·7	6·5	9	65·4	1	1	63·7	33	63·1
Mean force of wind	—	2·9	—	—	2·2	—	—	2·0	—	—	1·7	—	—	1·6	—	—	1·1	—	—	1·5	—	—	1·0	—	—	0

Malindi. Lat. 3·22° S., Long. 40·12° E. Observer: James Weaver.

Month	Mean Temp. 9 A.M. Dry	Mean Temp. 9 A.M. Wet	Humidity, 9 A.M. Dew Point	Humidity, 9 A.M. Vapour Pressure	Humidity, 9 A.M. Relative Humidity	Rain Amount	Rain Days	Rain Heaviest Fall
1899	°	°	°	In.	P.c.	In.	No.	In.
January	83·0	77·0	74·8	·860	76	0·02	1	0·02
February	84·2	76·7	73·9	·835	71	0·00	0	—
March	84·8	78·1	75·7	·887	72	0·80	4	0·60
April	84·4	78·5	76·4	·908	77	3·84	10	1·25
May	78·6	75·1	73·7	·831	85	17·63	20	5·30
June	77·7	73·6	72·0	·782	83	1·29	18	0·21
July	76·8	73·0	71·4	·768	83	5·87	21	0·83
August	77·1	72·9	71·1	·761	82	2·84	18	0·48
September	79·2	72·9	70·3	·739	74	0·22	3	0·12
October	81·8	75·1	72·4	·795	73	0·02	1	0·02
November	83·7	78·8	77·1	·928	81	0·71	4	0·46
December	85·0	78·8	76·6	·914	76	0·14	2	0·10
Year, 1899	81·4	75·9	73·8	·833	78	33·38	102	5·30
„ 1898	81·7	77·1	75·4	·882	81	14·44	53	1·65

Takaungu. Lat. 3·7° S., Long. 39·87° E. Observers: G. H. L. Murray and others.

Month	Rain Amount	Rain Days	Rain Heaviest fall in 24 hours
1899	In.	No.	In.
January	0·00	0	—
February	0·00	0	—
March	1·10	5	0·46
April	2·62	12	0·50
May	12·89	24	1·70
June	3·07	16	1·43
July	5·43	23	0·80
August	4·60	20	0·85
September	0·12	2	0·08
October	0·06	1	0·06
November	2·08	6	2·08
December	1·18	7	0·54
1899	33·15	116	2·08

Old Calabar. Lat. 4·97° N., Long. 8·28° E. Observers: Dr. E. G. Fenton and R. Allman.

Month	Mean Temperature Maximum	Mean Temperature Minimum	Extremes of Temperature Highest	Extremes of Temperature Lowest	Rainfall Amount	Rainfall Days	Rainfall Heaviest Fall	Prevailing Wind	Harmatans	Tornadoes
1899	°	°	°	°	In.	No.	In.		No.	No.
January	87·4	73·4	92	65	0·00	0	—	N.W.	22	—
February	92·4	77·3	96	70	1·48	5	0·91	N.W.	3	3
March	91·6	76·9	95	71	3·44	14	1·01	S.W.	—	8
April	91·0	76·1	97	69	9·87	17	2·12	S.W.	—	6
May	90·1	74·1	95	69	13·32	20	2·10	S.W.	—	6
June	88·3	72·9	91	70	9·33	21	1·85	S.W.	—	6
July	86·1	73·4	92	70	12·17	22	2·77	S.W.	—	3
August	85·3	72·2	88	70	20·72	20	5·45	S.W.	—	2
September	80·4	72·0	90	70	10·94	20	2·45	S.W.	—	1
October	85·0	73·9	90	70	6·28	15	1·32	S.W.	1	—
November	86·0	74·7	89	70	9·71	11	2·83	N.W.	2	4
December	85·9	76·5	89	72	0·34	4	0·8	N.W.	7	—
Year	87·5	74·4	97	65	98·60	169	5·45	N.W.	35	39

The observations are published as recorded.

The Revision of the Physical and Chemical Constants of Sea-Water.—Report of the Committee, consisting of Sir JOHN MURRAY (*Chairman*), Mr. J. Y. BUCHANAN, *F.R.S.*, Dr. H. R. MILL, Mr. H. N. DICKSON (*Secretary*). (*Drawn up by the Secretary.*)

THE Committee was appointed to co-operate in the investigations undertaken by Dr. Martin Knudsen at Copenhagen, at the instance of the Committee appointed by the International Conference held at Stockholm last year, with the view of making authoritative determinations of the constants used in reducing observations of the physical and chemical conditions of sea-water in different parts of the globe.

The grant placed at the disposal of the Committee has been expended in defraying part of the cost of Dr. Knudsen's researches.

Dr. Knudsen reports that the work of obtaining samples of water from different regions has been completed, except with regard to those from the East Greenland polar current, the northern part of the Baltic, and the Indian Ocean, which it is hoped will be received in about a month's time. The samples have been collected in six-litre bottles, prepared by standing full of hot water for a month before use. Dr. Knusden and his assistants began preliminary work in September last, and since May the regular analyses of samples have been carried on by himself, two chemists, and three physicists. The results obtained so far indicate that the methods employed are adequate in scope and precision, and sufficient progress has been made to justify the expectation that the work will be completed and published within the time arranged by the Stockholm Committee.

The Committee do not ask to be reappointed.

Future Dealings in Raw Produce.—Report of Committee, consisting of Mr. L. L. PRICE (*Chairman*), Professor A. W. FLUX (*Secretary*), Major P. G. CRAIGIE, Professor W. CUNNINGHAM, Professor F. Y. EDGEWORTH, Professor E. C. K. GONNER, Mr. R. H. HOOKER, and Mr. H. R. RATHBONE, *appointed to report on Future Dealings in Raw Produce.* (*Drawn up by the Secretary, with the assistance of* Mr. HOOKER.)

[PLATE IV.]

THE markets in which organised dealings for future delivery are carried on are concerned with many kinds of raw produce. It appears to the Committee that the circumstances of the markets which are concerned with such products as wheat, maize, cotton, and the like are so different from those in which the metals are dealt in, that no advantage would result from presenting an investigation of the two groups on common

lines. The one group of commodities manifests the general characteristic that the supply is not continuously produced, but that, speaking broadly, the supply for a year depends upon the results of a harvest which falls within a limited part of the year ; the demand for consumption is, however, one which exists throughout the year, being roughly continuous. The work of dealers in these commodities is, therefore, to arrange relations between a spasmodic supply and a continuous consumption. With products of which metals may be taken as the type, there does not exist the same dependence of supply on the round of the seasons. Demand fluctuates ; but supply can, if necessary, be organised so as to provide a continuous output calculated to meet a steady demand of large or of small dimensions. It seems reasonable to suppose that the influence of the market organisation for future dealings on price and supply will not follow identical lines in cases so widely contrasted. As, further, the interest in the subject referred to the Committee is, in the main, derived from the questions raised in reference to farm products (and particularly in reference to grain), the Committee propose to confine their report to this section of the material which the reference to them might be considered to cover. Should the questions connected with future dealings in metals appear of sufficient interest, a separate investigation may be directed into that subject by a committee suitably constituted.

The problems which arise in connection with future dealings in produce are in some respects not unlike some of those which are discussed in Sir Robert Giffen's essay on Stock Exchange Securities,[1] but differences fundamental in their nature distinguish the cases of stock and produce dealings. If no other difference existed, the fact that the existing supply of raw cotton (for example) will be, in the main, used up in the course of a year, while at the end of a year the bulk of the existing Stock Exchange securities will still be found in existence, would differentiate the two problems sufficiently. The influences which determine the level of values are certainly not identical in the two cases, so that the points which are of greatest importance in the discussion of the Stock Exchange will not necessarily need to be equally fully considered here, nor will the conclusion in regard to what Sir R. Giffen designates 'fictitious securities' be capable of simple application to what is sometimes called 'fictitious grain.'

It may be not superfluous to sketch the leading features of the market organisation, the influence of which we seek to trace. In so doing, it will be necessary to remember that we have not simply to consider bargains, the fulfilment of which is contracted to take place at some future date. It need not be argued that such bargains are regularly made in every department of life, and that no very special interest attaches to the investigation of the influence of the custom of making contracts which, from the nature of the case, are incapable of instant fulfilment. Moreover, such contracts are, in many cases, eminently speculative, though greater speculation may occur in cases where no such contract is made. The builder who undertakes to build a Town Hall at a definite price is making a contract for future delivery of goods ; but it is the builder who erects houses with the expectation of disposing of them when finished—who makes, in respect of them, no contract for delivery at a definite price and time—who is commonly referred to as the 'speculative' builder. It is

[1] *Stock Exchange Securities: An Essay on the General Causes of Fluctuations in their Price.* By Robert Giffen. 1877.

not unnecessary to recall such facts, inasmuch as some confusion frequently arises in reference to the relation of 'futures' and 'speculation.'

As stated, then, the problem which needs investigation is not the influence on price movements of forward contracts, such as the purchase and sale of a cargo of wheat actually on passage which may be sold in anticipation of its arrival, but of an entirely different class of contracts. In these contracts one leading feature is that the goods bought and sold are not dealt in by sample, but their quality is determined by reference to certain standards established by some responsible organisation. In wheat the standard may be, for example, as in London (for American wheat), *No.* 1, *Northern*, or, as is usual in Liverpool, *No.* 2, *Winter* (or *Spring*); in cotton, it may be what is known as *middling* uplands when American cotton is in question, *fully good fair* for Egyptian, and similarly in regard to other commodities. The buyer need not be able to discriminate between good and bad wheat, he may conceivably not be capable of distinguishing wheat from barley, but the quality of the wheat to which he becomes entitled is nevertheless determinate. Rules are laid down by the Associations of Grain Dealers in leading centres such as Chicago, Duluth, New York, Liverpool, &c., for maintaining the standard according to which any actual parcel of wheat is determined to be of standard grade or not, the American centres further grading into several classes, under Government supervision. One distinction between dealing by sample and dealing in standard grades is that in the former case slight differences would be likely to exist between the qualities to which any two bargains had reference; in the latter case all bargains in a standard grade are on the same level in the matter of the quality of the produce which is capable of being used for their fulfilment. Further, by custom or by rule, the quantity dealt in on any contract is, if not the same, always a multiple of a standard quantity, *e.g.* 4,800 or 5,000 centals of wheat in London and Liverpool respectively.

If, then, the date named for delivery be the same for any two contracts (and the custom of naming, not a day, but a month, or two months even, within which delivery may be made, helps to produce ready coincidence in this matter), the only point of difference remaining is the price. Different contracts for the delivery in one and the same month of the same number of units (of wheat or cotton or other produce) of the usual standard grade will, except in the matter of price, be as nearly identical and as interchangeable for all practical purposes as two bonds of a municipality for equal amounts, if not as much so as two Bank of England notes of the same denomination. To the man who has bought and sold equal amounts of the same grade for the same period of delivery there remains no concern in the actual goods; he is concerned merely in the relation of the prices of the sale and purchase.

But a further development of the organisation of markets where this class of business is largely transacted is also of importance, as affecting the facilities for carrying on such dealings, namely, the establishment of Clearing Houses, and the introduction of a system of periodical settlements. These are effected daily in some cases, weekly in others, while in some markets no settlement takes place before the term of the bargain has expired.

To indicate the purpose and operation of clearing-houses and short settlements, reference to a hypothetical example may be made. Suppose that in January A sells 50,000 centals (or, say, 10,000 quarters) of wheat to B.

(The standard grade need not be here specified, provided that the fact that the bargain is one in wheat of a named standard grade be remembered.) The wheat is to be delivered in May, and the price to be paid is, say, 6*s.* per cental. Suppose the term to run out and that B has not found a convenient opportunity of reselling at a profit—in fact, that he expected that the price would rise, while it falls steadily and persistently. When May comes B must either take charge of the wheat and pay for it in full, or, if he has no facilities for doing so, will be forced to sell; in fact, the latter may be his only means of providing the funds with which to pay for his purchase. If the price has fallen to 5*s.* 6*d.*, he realises 1,250*l.* less than he needs to make this payment. Should this be not a solitary contract, but one of a score, averaging equally bad results, the dealer, if not a wealthy man, may find it difficult to provide the means of paying for his purchases, and his bankruptcy may prevent such payment being made.

The holder of the wheat, A, may find that such a failure of B leaves him to sell the wheat as best he can, and face the loss the risk of which his sale to B ought to have removed from his shoulders. The short-settlement system aims at reducing the risk of loss due to the assumption by weak dealers of risks greater than the funds at their disposal enable them to cover, and thus at rendering business more secure, and, being more secure, capable of being carried on with narrower profits. The parties to the contract may (or in some cases must) deposit a sum of money sufficient to cover any probable loss due to variation of price for a short time, and, if prices vary beyond what the deposit can make good, must increase the deposit. Thus, in the above case, the deposit may have been, say, 5 per cent. of the contract price, or 750*l.* Should the price fall so as to indicate to one party the loss of the whole of this margin in case of realisation at the price of the day, he may decide that it is better to accept so much of loss than to risk a greater, and he is helped to this decision by the need of providing the means of meeting a greater loss, should it occur. The man who would be most likely to fail to meet his obligations on their maturity being, in general, the man most likely to find it difficult to spare the deposit money from his business capital, is precisely the man who is, so to speak, warned off by the pressure of the need to maintain the deposit. In the case assumed, were the official price to fall to 5*s.* 11*d.* on some day shortly following the conclusion of the contract, the buyer would be required to find 50,000 pence, or 208*l.* 6*s.* 8*d.*, and to pay it, together with a further margin. Should a further fall occur he would need to pay a corresponding sum, while, in case of a recovery, he would be entitled to receive part of his deposit again. This necessity to face losses as they occur may be a hardship to a man whose ultimate forecast of profit is realised, should the market go against him steadily and heavily for a considerable part of the period between the contract and the due date of its fulfilment. Yet, on the whole, the short-settlement system and the putting up of margins do certainly tend to prevent men from assuming risks beyond the power of their means to cover. The fact that, to persons who would have no desire to make a contract for future delivery of goods and to accept delivery in due course, a facility is afforded to operate on the market and to attempt to snatch profits fron day-to-day fluctuations in prices, the daily (or weekly) settlement enabling them to make their attempt and be very shortly free of all responsibility in regard to it, not needing even to wait for the distant delivery month for the realisation of

the profit (if any) they may make, has been used to cast odium on the system of short intermediate settlements. It is true that the system does offer facilities for speculation in mere price-movements as distinct from dealing in commodities, but the other fact must also be borne in mind that it serves to check wild speculation by weak dealers unable to meet the losses which they were nevertheless very ready to face before the system was introduced.

The example of direct dealing between two persons, which has been used, will not serve to give an accurate idea of the situation. It is common to have a large number of persons involved in such transactions. Not only have we A selling to B, but B to C, C to D, and so on for a score of links perhaps. The liquidation of such a transaction is greatly facilitated by bringing the first seller and the last buyer into direct relations with each other, since the intermediate dealers are concerned (unless in case of a failure to fulfil contracts) only with the differences between the prices at which they have bought and sold respectively. The unravelling of the complex series of payments and passing of delivery orders, &c., which, in a long series, involved delay and difficulty when no organisation for the purpose existed, is, in many leading markets, accomplished through the medium of a clearing-house. It is unnecessary to describe the organisation in any detail,[1] though the existence of these facilities must be borne in mind, inasmuch as purely speculative transactions, as well as the process of dealing in which actual delivery of goods takes place, appear to profit by them. In particular, one feature has attracted some attention and provoked adverse criticism, namely, that where the necessities of business bring about a state of things in which the original seller becomes in turn a buyer of the same delivery, the series of dealers, A, B, C, D, &c., ends as well as begins with A, and the passing of any warehouse receipt or other form of claim to a specific lot of goods becomes a mere form. The interests of all parties in such a closed ring are confined to price differences. The settlement of such transactions by the process of 'ringing out,' when an invoice and a formal tender are passed round the ring, appears to some to indicate an objectionable facility afforded to those who practically bet on price-changes, and it is apparently desired in some quarters to suppress these facilities in order to suppress the transactions thus described.

The result of the elaborate organisation of markets for dealing in futures in commodities is that it has become possible to buy or sell for future delivery without difficulty, and at prices publicly and regularly quoted. Those who desire to ensure supplies of any commodity for which a market so organised exists can do so without difficulty, while those who desire to secure themselves against future fluctuations in the price of raw produce, whether as buyers or sellers, are provided with the means of doing so.

Attention must be particularly given to the use of dealings in futures in providing insurance against price-changes, for no small amount of importance attaches both directly and indirectly to this. It accounts, in part, for the fact, so troublesome to some critics, that far larger amounts of produce are sold for future delivery than could possibly be delivered. The tenderable quality is determinate, and though there

[1] For details as to cotton dealings in Liverpool, *cf.* Ellison's *Cotton Trade of Great Britain*, chap. iv.

may be enormous quantities of produce of inferior quality, it cannot be tendered in fulfilment of an ordinary future contract; or, if tenders below the standard quality are, as in some cases, permitted, the limits of such deficiency in quality which are acceptable are narrow, and a pecuniary allowance must be made for the deficiency.

The purchase or sale of regular futures-contracts is made, however, to serve as a hedge against too great loss from the variation in price of classes of produce not actually deliverable on such contracts, and, indeed, for some dealings in goods produced from the raw material to which contracts refer. This use of the futures-contract depends on the fairly close accord between the movements in price of different qualities of the same commodity. The accord is not exact, but it generally suffices to render the hedge effective in some degree. To illustrate, we take the spot prices of middling American cotton and good fair Pernambuco at Liverpool on March 29 and May 17 of the current year. The former stood at $5\frac{7}{16}d.$ at the earlier date, $5\frac{7}{32}d.$ at the later. The Pernambuco quotations were $6d.$ and $5\frac{3}{4}d.$ Of the variation of $\frac{1}{4}d.$ shown in the latter price, $\frac{7}{32}d.$ were shared by the former. Hence, in a great degree, futures in American would have served as a hedge against variations in price of Pernambuco almost as well as against variations in price of American itself. As a direct insurance in dealings in the same commodity as that named in the futures-contract, that contract is obviously serviceable. An importer who purchases a shipload of wheat, anticipating to sell it on arrival at a certain price, will sell futures to an amount corresponding to the quantity of actual wheat he has bought. If the price has fallen when the goods arrive, the amount received from their sale will be reduced, but, on the other hand, the cost of repurchase of the futures-contract will have also fallen, and to an amount which will cover the bulk, if not the whole, of the loss on the sale of the actual grain. So, also, in case of a forward sale, the risk of loss through price-variation may be effectively insured against by a purchase and subsequent resale of a futures-contract.

The facility of dealing in these contracts, then, affords a means of reducing risk of financial loss in the handling of the actual produce, both that which is of such quality as to be tenderable on the contracts, and that which is not of such quality. Its use in covering the latter class of dealings leads to a considerable excess of dealings in futures over actual deliveries of tenderable grades. Now, in considering the influence on prices of the modern system of dealings in futures, the reduction of the risk assumed by various sections of dealers must be given a prominent place. The margin of profit which is sufficient to support dealings of a comparatively safe character is much smaller than that necessary when risk is considerable. Even though the goods pass through the hands of more numerous dealers than formerly, the cost of handling may be reduced through the reduction of the risks of the dealers. We have been unable to obtain any satisfactory means of determining to what extent the cost of handling (apart from elevator charges and freight charges) has been reduced, but we have seen no reason for supposing that it has been increased, as seems to be suggested by some who direct attention to the large number of hands through which a futures-contract may pass, and the accumulation of commissions which is suggested in consequence. The fact that dealings in wheat futures in Liverpool, for example, amount to from twelve to twenty or thirty times the amount of

the wheat actually tendered against these dealings, does not necessarily imply that every quarter of imported wheat has to bear the weight of a score of commissions to brokers for handling futures-contracts.

It seems hardly necessary to repeat at length what has been sufficiently often made clear, that the futures-contract entered into by a dealer who actually proposes to demand delivery of, or make a tender of, the produce represented by it, cannot be distinguished from the contract entered into by a dealer who does not propose to handle either the goods named in the contract or any other goods in respect of the price-variations of which the said contract may be used as a hedge. The point may be made clear by giving an example of the actual form used, selecting for that purpose the following :—

No. 26.—FUTURE DELIVERY CONTRACT—AMERICAN RED WHEAT.

THE LIVERPOOL CORN TRADE ASSOCIATION,

LIMITED.

This Contract was made on the date specified, and within the business hours fixed by the Liverpool Corn Trade Association, Limited.

LIVERPOOL,..........................189.........

We have this day SOLD to...on the terms of the Printed Rules of the Liverpool Corn Trade Association, Limited, ...say.............................Centals American Red Wheat (grown East of the Rocky Mountains in the United States of North America and/or Canada), of quality not lower than the Standards of No. 2 Winter or No. 2 Spring, as adopted by the Liverpool Corn Trade Association, Limited, and in force for the specified time of delivery, at.......................per 100 lb. to be delivered during..................................ex store, in Liverpool, or, at Sellers' option, in Birkenhead at an allowance to the Buyers of One Farthing per cental. The Wheat to be in fair merchantable condition ; a slight dry warmth not to be objected to.

Payment—as per Rule 8, allowing interest equal to three months from date of being ready for delivery.

This Contract is made between yourselves and ourselves, and not by or with any person, whether disclosed or not, on whose instructions or for whose benefit the same may have been entered into.

Amended 18th October, 1897.
In force on and after 1st January, 1898.

....

Entered at Stationers' Hall and sold only at the Clearing House of the Association.

The examination of this form will suffice to show that it would be a practical impossibility to distinguish the simple gambling from the (so-called) legitimate dealings for the purpose of suppressing the former.

Apart from objections to gambling as gambling, the allegations as to the effect of modern dealings in futures appear to attribute to them influences of two kinds : (*a*) that they tend to depress prices, and are in fact responsible for much of the fall in price of such commodities as wheat and cotton which has taken place in the last twenty-five years ; (*b*) that they cause market-prices to be much less steady than they would be if left to be

determined by the transactions of dealers handling the actual goods alone. It will be convenient to consider these views separately, and to make such comparisons of the actual course of market-prices as seem most likely to throw light on the subject.

First is the influence on the general price-level. The reason for asserting that this has been depressed by dealings in futures appears to be, when the statements of the advocates of this view are considered, chiefly that other causes are inadequate to produce the result actually experienced. We do not think it is necessary to support our dissent from this view by indications of the influences to which the fall in some prices, especially those of wheat, maize, and other grain, should be attributed. To do so would be to travel far outside the matter referred to us. It will suffice to say that we hold it to be necessary to show how the operation of the futures-market can depress the general price-level of the goods dealt in. In only one way can we admit a real depressing influence, and that is through reducing the cost of handling: *i.e.*, the price may be reduced to the consumer without a reduction of price to the producer of the raw commodity by cheapening the marketing (as well as the freight) charges. Such a reduction of price would reduce the return to all those producers between whom and the consuming regions but little expense of carriage intervened. It is an important point to examine, therefore, whether the return received by the American farmer in the great wheat-producing areas has been reduced largely—whether it has been reduced as much proportionately as have prices generally. This is a point not very easy to determine. The U.S. Department of Agriculture compiles a figure which is given as the average farm-price of wheat at the beginning of December. Comparing this with the average export-price of wheat from the U.S., we have (see for extended table Appendix) :—

Years	Average farm price. Cents per bushel	Years ending June 30	Average export price. Cents per bushel
1869–78	104·7	1870–79	127·6
1889–98	66·5	1890–99	79·7

These figures indicate a fall of not very different proportions in the two prices. The freight-rates from Chicago to New York,[1] compiled by Mr. J. C. Brown, of the New York Produce Exchange, show a reduction of the all-rail rate of over 12 cents per bushel, of the lake-and-rail rate of 11 cents, and of the lake-and-canal rate of over 9 cents, comparing the same two periods.

Average Rates. Cents per Bushel.

Years	Lake and Canal	Lake and Rail	All Rail
1870–79	14·8	18·6	25·6
1890–99	5·2	7·3	13·0

The reduced cost of transportation seems, in the light of these figures, capable of accounting for all, and maybe more than all, the difference between the fall in the farm and export prices. If these figures were really representative, the conclusion would be that charges other than freight have possibly increased, since the fall in price falls short of the fall in freight, by the all-rail routes, between Chicago and New York.

[1] Cf. *Statistical Abstract of the United States.*

It is not, however, satisfactory to compare the fall of price at a particular date in the year on the farm with the average fall registered in a year. A distinctly useful corrective to the idea that the prices of recent years at places near the great producing regions are without precedent, is afforded by the record of monthly averages of prices of wheat at Cincinnati which are given in the 'Cincinnati Price-Current' (for table see Appendix). The range of prices of the ten years 1844–53 would compare quite closely with those of the past fifteen years. The lowest figures, those of 1894, do not touch the level reached in the course of 1846. It is true that for long periods—for example in the dozen years ending 1882—the fluctuations of price centred about a level some 50 per cent. above that about which the fluctuations of 1844–53, or those of the years since 1885, have centred. But it does not seem necessary to invoke the aid of the modern market organisation to account for a return to the level of half a century ago.

It is further of importance to recall the fact that in another great staple, cotton, the lowest prices of recent years hardly fell below those registered early in the century. The table of average prices of middling American cotton, which is given in the Appendix (*cf.* p. 435), shows that, whatever may be the influences which have depressed the prices of cotton of late years, the level reached is practically that of the period before the American Civil War. Any suggestion of the need of an influence from the futures-market to produce the actual result would appear unnecessary.

It may be granted that absolute certainty cannot, on this point, be reached from the examination of statistical compilations. A consideration of the matter from the point of view of the probable influence of an active futures-market, however, shows no point where a permanent depressing influence can arise. The facilities for short-selling are, it is true, considerable, but the 'bear' must cover his sales, and hence he must, in the end, support the market by buying. And, it may be added, the organisation affords as great facilities to the 'bull' as to the 'bear,' so that, whatever the effect on the fluctuations of price, the increase of both buying and selling would hardly produce a strong pressure which, in the long run, is all in one direction. The depressing effect of sales of wind-wheat is hardly the same as in the stock markets is produced by the introduction of fictitious securities. The sales, as stated, must be covered by purchases, and that within a limited time. Hence the nature of the commodities 'fictitious wheat' and 'fictitious securities' is not the same.

A not uninstructive illustration is afforded by the recent experience of the Berlin market. As a result of the Bourse Law of 1896, the active dealings in that market have been restricted within very much narrower limits than formerly. The form of contract which is no longer legal there is still legal in Liverpool, London, Amsterdam, and elsewhere, and to these centres much of the business formerly transacted in Berlin is practically transferred. Berlin is cut off from that close contact with the world-market which was maintained so long as the methods of transacting business there were similar to those in use elsewhere. The result is shown in the annexed table (p. 430), showing the average level of price in Liverpool, Amsterdam, and Berlin in each of the last eight years, from which it will be seen that the check on futures business in that market has certainly not raised the price there relatively to that on the great markets of the world. Berlin prices have shown, indeed, a smaller excess over those representing the free markets of Europe since than before the Bourse

Law. It should be added that there has been no change in the customs duty on wheat or rye to nullify the comparison.

Year	Wheat, per 100 lb.		Rye, per 100 lb.	
	Berlin	Liverpool (Californian)	Berlin	Amsterdam
	s. d.	s. d.	s. d.	s. d.
1892	7 8½	7 1½	7 8½	5 9¾
1893	6 7½	5 10¼	5 10¼	4 7¾
1894	5 11½	4 11¼	5 1¾	3 7½
1895	6 2¾	5 2½	5 3	3 7½
1896	6 10	5 10¼	5 2¼	3 8¾
1897	7 7¼	7 1	5 8¼	4 3
1898	8 1½	7 6¼	6 4¾	5 2½
1899	6 9½	6 3	6 4¾	5 3½

Reference may also be made to the fact that the active operation of a market in futures has not in every case been accompanied by a declining level of price. A conspicuous example to the contrary is coffee.

The second, and in some sense alternative, suggestion as to the effect of dealings in futures, is that they result in greater unsteadiness of price than would exist without them. Here what may be called the theoretical presumption is rather of an opposite tendency. In the weeks following harvest, the pressure of abundant supply is likely to depress prices less, when, on the demand side, the provision for the whole season is regularly influencing buyers through the operation of a well-organised machinery; while a secured provision for future needs through the same means seems likely to modify the pressure of buying in a market which for some reason is temporarily short of supplies. An active market will show more numerous small fluctuations, but the greater movements will, in the majority of cases, be reduced in intensity as the natural result of active dealings in futures. Corners are not excluded, but the growing magnitude of operations is, as experience sufficiently shows, rendering successful manipulation of corners more and more difficult. An active market is frequently a sensitive market and subject to scares, but it is able to recover from these scares more completely and rapidly than an inactive market. The world-wide range of operations is a constant influence in restraint of manipulations contrary to the general movements which the actual state of supply and of demand tends to set up. The dealers who sell short in anticipation of a fall, or attempt to control supplies in order to profit by a rise, must either possess such large resources as to be able to force the market to move as they wish (and this, as stated, is becoming increasingly difficult on any extensive scale), or they must gauge correctly the movements before they set in. If dealers persistently opposed the trend of prices as resulting from actual supply and demand, they would as persistently lose, which would, in the long run, mean their disappearance from the market. In anticipating a movement which would in any case be realised, the force of the movement is likely to be modified.

The attention of the Committee has been given to the possibility of measuring the comparative degree of stability of prices before and since the creation of the great trading in futures. For the purpose of gauging the relative degrees of fluctuation, in different markets and at different times, two indices have been worked out. One is the well-known *Stan-*

dard Deviation, or, as it is sometimes called, the *Probable Error*, of a series of quotations as compared with the mean of the whole series employed. It seemed possible, however, that some serious fluctuations would escape notice in this measure, in cases where rapid but only moderately violent movements, now upwards, now downwards, characterised the market quotations. A few very large variations seemed capable of outweighing numerous smaller but quite serious movements. To avoid possibility of a misleading result, therefore, the mean actual difference between each quotation and that immediately following it has also been calculated, and forms a second measure of the degree of variability of the price. In these comparisons the movements of wheat prices have been deemed sufficient.

The available series of daily quotations did not extend over a sufficiently long period to make their use for our purpose quite satisfactory. To test in some degree how far less frequent quotations might be used without greatly disturbing the index obtained, some calculations were made of the Standard Deviation for certain daily quotations and other weekly quotations. The results indicate that the relative intensity of fluctuations may be fairly well measured by weekly prices.

It may be added that the S.D. of a series of weekly prices coincided with remarkable closeness to that of a monthly series derived from them over a period of half a century. The percentage of standard deviation to average price is not widely different in the two cases. We have, therefore, considered that the relative steadiness of prices may be sufficiently indicated from the weekly prices afforded in the Gazette Average Price of English Wheat. Has the English farmer been subject to a less or greater degree of fluctuation in the price of his wheat since futures-markets have dominated those prices?

In the diagram annexed (see Appendix, Plate IV.), and in the tables which accompany it, the comparison over fifty years is shown. Calendar years have been used because the use of a fixed date from which to reckon the cereal year introduced the difficulty that it sometimes threw price-movements of two harvests into one so-called cereal year. Were the cereal year able to be taken, the fluctuation shown might be somewhat reduced. The computation of the S.D. for these years, making each year begin with September, has been made, and no great difference would be shown had those results been plotted on the diagram in place of those for calendar years. The summary of the tables in the Appendix is as follows:—

Gazette Average of English Wheat.

Period	1850–59		1860–69		1870–79		1880–89		1890–99	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
Average Price *s. d.* per quarter .	53	4	51	9	51	5	37	0	28	9
Standard Deviation	4	$4\frac{1}{8}$	4	$1\frac{1}{8}$	3	$10\frac{1}{4}$	1	$11\frac{3}{4}$	2	$6\frac{3}{4}$
Mean Weekly Movement . .	0	$10\frac{7}{8}$	0	$8\frac{3}{8}$	0	$7\frac{3}{8}$	0	$5\frac{5}{8}$	0	$5\frac{1}{8}$

The gradual narrowing of the range of variation is a noteworthy feature of the table. The fact that, considered as a percentage of the price, the variability has hardly been reduced, is equally noteworthy; but it is a disputable point whether the actual money amount of the variability is not rather to be taken into account than the percentage

variability. Attention may be especially called to the fact that, except for the disturbance due to the Leiter corner, the period of comparative stability in the Gazette Average Price, stability in the sense of freedom from violent fluctuations, sets in precisely at the time when the organisation of the futures-markets had reached that stage to which their opponents attribute malign results.

A comparison of the relative variability of prices in different centres is also not without interest. In the following table the movements in Berlin, New York, Chicago, and Liverpool are compared in each of the last four years, in shillings and pence per cental of 100 lb.

—	1896	1897	1898	1899
	s. d.	*s. d.*	*s. d.*	*s. d.*
Berlin: S.D.	$5\frac{3}{8}$	$6\frac{3}{8}$	$11\frac{1}{4}$	3
M.D.M.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{8}$
Average Price	6 $9\frac{7}{8}$	7 $7\frac{3}{4}$	8 $5\frac{3}{8}$	6 $10\frac{11}{16}$
	Winter Wheat	Spring Wheat	Winter Wheat	Winter Wheat
New York: S.D.	$8\frac{1}{4}$	$7\frac{5}{8}$	1 $7\frac{1}{16}$	$3\frac{7}{16}$
M.D.M.	$\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$
Average Price	5 $5\frac{1}{4}$	6 $3\frac{7}{8}$	6 $7\frac{1}{8}$	5 $6\frac{1}{8}$
Chicago (Spring): S.D.	$6\frac{1}{8}$	$6\frac{3}{8}$	1 $8\frac{7}{8}$	$2\frac{1}{8}$
M.D.M.	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{5}{8}$	$\frac{1}{2}$
Average Price	4 $5\frac{1}{4}$	6 $2\frac{1}{8}$	6 $1\frac{3}{4}$	4 $11\frac{1}{2}$
Liverpool: S.D.	—	$9\frac{5}{8}$	1 $5\frac{1}{2}$	$1\frac{1}{2}$
M.D.M.	—	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{4}$
Average Price	—	6 $9\frac{5}{8}$	7 $5\frac{3}{8}$	6 $0\frac{1}{8}$

S.D. = Standard Deviation, M.D.M. = Mean Daily Movement.

The restrictions imposed on Berlin business have not, apparently, increased the steadiness of prices, which is a feature in which an influence was anticipated by the advocates of the restriction.

We have failed to find any conclusive evidence in favour of the theory that prices have been depressed as a consequence of the development of markets for future delivery business, and have found reason for believing that in point of steadiness some change for the better is traceable since the influence of these markets became great. These conclusions are in accord with the deductions which a theoretic examination of the question yields.

In what precedes the word 'futures' has been uniformly used to indicate the kind of business contemplated. The distinction between the contract for delivery within a definite future period of time and the contract which confers the right to demand that such a bargain shall be entered upon at a definite price seemed to be conveniently made by reserving the name 'option' to the latter class of contract, although actual practice in this matter is not quite definite and consistent. To make a distinction not always made in practice seemed calculated to avoid confusion.

APPENDIX.

TABLE I.—*Wheat and Maize: Average Farm Price, Average Price at Chicago and New York, and Average Export Price in Cents per bushel.*[1]

	Wheat				Maize			
Year	Average Farm Price	Chicago	New York	Average Export Price	Average Farm Price	Chicago	New York	Average Export Price
1840	—	44	103½	95	—	43½	57	—
1841	—	46	113	95	—	31	60	—
1842	—	—	113	112	—	27	61½	—
1843	—	47	94½	85	—	29	53½	—
1844	—	55	96	90	—	41	50	—
1845	—	52	97½	86	—	36	50½	—
1846	—	40	103½	104	—	25	65	—
1847	—	53	135	137	—	27½	84½	—
1848	—	72	121	131	—	33	63	—
1849	—	59	104	114	—	40½	61	—
1850	—	63	106	106	—	34	61½	—
1851	—	54½	95½	100	—	33	63	—
1852	—	41	103½	95	—	37½	66	—
1853	—	75	130½	112	—	47	71	—
1854	—	97	184	155	—	46	76½	—
1855	—	134	210	166	—	58½	94	—
1856	—	113	159	185	—	42½	69	—
1857	—	93	148½	153	—	46	73	—
1858	—	62	105	102	—	41	68½	—
1859	—	77	123	95	—	—	85½	—
1860	—	97½	124	98	—	—	73	—
1861	—	71½	111	123	—	—	59	64·1
1862	93·7	73½	118½	114	34·8	—	59	55
1863	114	97	126½	129	69·9	—	83½	65·8
1864	183·1	140½	183½	133	99·5	—	144	81·8
1865	146·3	117	175½	194	46	—	123½	130
1866	219·6	115½	181	141	68·2	—	88	81·9
1867	199	193	228	127	79·5	—	117½	100
1868	142·4	176	213	190	62·8	—	120	117·5
1869	94·1	114	145½	139	75·3	—	100	96·8
1870	104·2	92	118	129	54·9	—	99½	92·5
1871	125·8	121	148	132	48·2	49½	77	75·9
1872	124	120½	155½	147	39·8	39	70	69·5
1873	115·1	114½	156½	131	48·5	33	63	61·8
1874	94·1	113	142½	143	64·7	64	85	71·9
1875	100	101	121	112	42	64½	81½	84·8
1876	103·7	102½	123	124	37	45½	62½	67·2
1877	108·2	127	149	117	35·8	43½	58	58·7
1878	77·7	99½	121½	134	31·8	39	53½	56·2

[1] Average farm prices from Reports of U.S. Department of Agriculture. Prices at Chicago and New York (spring wheat) from the U.S. Senate Report of 1893 on Wholesale Prices, Wages, and Transportation from 1840 to 1891; and for later years, for New York (winter wheat), from the U.S. Statistical Abstract, and for Chicago from Messrs. Howard, Bartels, & Co.'s Record of Statistical Information.

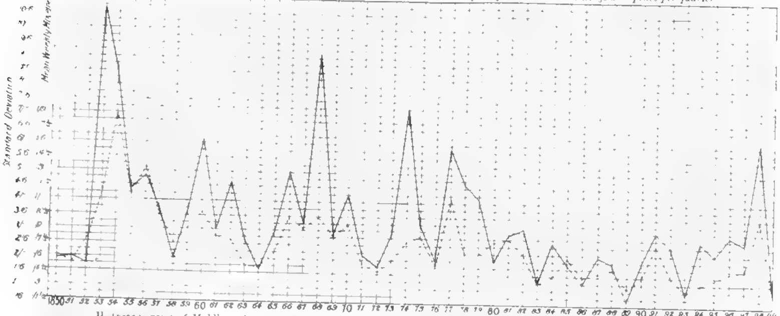
Table I. (continued)—*Wheat and Maize: Average Farm Price, Average Price Chicago and New York, and Average Export Price in Cents per bushel.*

	Wheat				Maize			
Year	Average Farm Price	Chicago	New York	Average Export Price	Average Farm Price	Chicago	New York	Average Export Price
1879	110·8	95	116	107	37·5	33½	47	47·1
1880	95·1	106½	123	125	39·6	37	55	54·3
1881	119·2	112½	125	111	63·6	49	61½	55·2
1882	88·2	122½	129	119	48·4	66	76	66·8
1883	91·1	99½	106	113	42·4	50½	64	68·4
1884	64·5	85	95½	107	35·7	54	61	61·1
1885	77·1	82	90½	86	32·8	41	52	54·0
1886	68·7	77	87	87	36·6	36	47	49·8
1887	68·1	75	87	89	44·4	38½	48½	47·9
1888	92·6	84½	92½	85	34·1	48	58½	55·0
1889	69·8	90½	95	90	28·3	34	43	47·4
1890	83·8	85	91	83	50·6	35	43½	41·8
1891	83·9	95½	106	93	40·6	57	67	57·4
1892	62·4	79	91	103	39·3	46	54	55·1
1893	53·8	68	74	80	36·5	39	50	53·4
1894	49·1	57	61	67	45·7	43	51	46·2
1895	50·9	62½	67	58	25·3	40	47½	52·9
1896	72·6	66½	78	65	21·5	26	34	37·8
1897	80·8	86	95½	75	26·3	25½	32	30·6
1898	58·2	90	95	98	28·7	31½	37½	35·5
1899	58·4	71½	79½	75	30 3	33½	41½	39·6

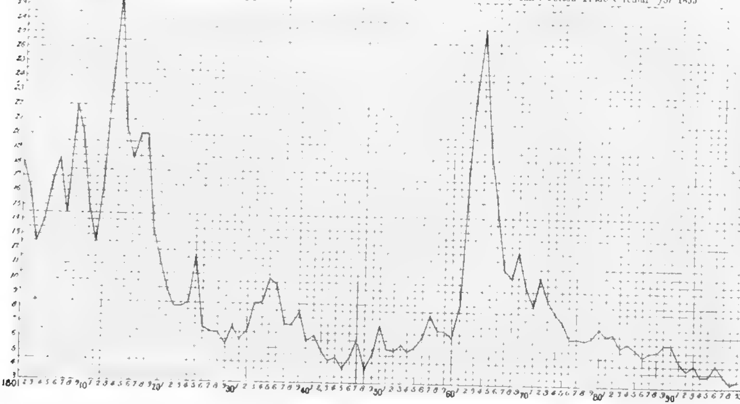
TABLE II.—*Price of Wheat at Cincinnati. Cents per bushel.*

Year	Price	Year	Price	Year	Price
1844	69	1863	79	1882	117
1845	70	1864	82	1883	107
1846	60	1865	115	1884	91
1847	83	1866	180	1885	93
1848	78	1867	192	1886	82
1849	78	1868	156	1887	79
1850	86	1869	101	1888	92
1851	66	1870	100	1889	84
1852	62	1871	121	1890	89
1853	85	1872	141	1891	99
1854	134	1873	132	1892	81
1855	156	1874	108	1893	64
1856	114	1875	100	1894	54
1857	107	1876	89	1895	66
1858	83	1877	131	1896	72
1859	117	1878	96	1897	89
1860	115	1879	104	1898	—
1861	89	1880	109	1899	—
1862	81	1881	121		

I Standard Deviation and Mean Weekly Movement of 'Gazette' Price of English Wheat. Shillings and pence per quarter



II Average price of Middling American Cotton at Liverpool, in pence per lb. From 'Tattersall's Cotton Trade Circular' for 1899



Illustrating the Report on Future Dealings in Raw Produce.

TABLE III.—*Average Gazette Price of English Wheat, Standard Deviation and Mean Weekly Movement. Shillings and Pence per Quarter.*

Year	Average Price		Standard Deviation		Mean Weekly Movement	Year	Average Price		Standard Deviation		Mean Weekly Movement
	s.	*d.*	*s.*	*d.*	*d.*		*s.*	*d.*	*s.*	*d.*	*d.*
1850	40	3	1	$11\frac{1}{4}$	6	1875	45	2	3	$3\frac{1}{2}$	$8\frac{1}{2}$
1851	38	7	2	$0\frac{1}{2}$	$5\frac{3}{8}$	1876	46	3	2	$0\frac{1}{2}$	$5\frac{3}{8}$
1852	40	10	1	$8\frac{7}{8}$	$7\frac{7}{8}$	1877	56	10	5	$10\frac{7}{8}$	$12\frac{1}{2}$
1853	53	1	10	$7\frac{3}{8}$	13	1878	46	5	4	$7\frac{1}{8}$	$6\frac{7}{8}$
1854	72	5	8	$6\frac{1}{4}$	$20\frac{7}{8}$	1879	43	11	4	$1\frac{1}{2}$	$6\frac{5}{8}$
1855	74	9	4	$4\frac{1}{4}$	$12\frac{5}{8}$	1880	44	4	1	$11\frac{1}{4}$	8
1856	69	2	4	10	$15\frac{1}{2}$	1881	45	5	2	$10\frac{7}{8}$	$8\frac{1}{4}$
1857	56	5	3	$9\frac{3}{8}$	$10\frac{7}{8}$	1882	45	1	3	$1\frac{3}{4}$	7
1858	44	3	1	$11\frac{3}{4}$	$7\frac{5}{8}$	1883	41	7	1	$3\frac{5}{8}$	$3\frac{1}{8}$
1859	43	10	3	$7\frac{1}{2}$	9	1884	35	9	2	$7\frac{7}{8}$	$4\frac{3}{8}$
1860	53	3	6	$0\frac{7}{8}$	$10\frac{7}{8}$	1885	32	10	1	$10\frac{1}{4}$	$6\frac{1}{2}$
1861	55	4	3	$0\frac{7}{8}$	$8\frac{3}{8}$	1886	31	1	1	$2\frac{3}{8}$	$4\frac{1}{4}$
1862	55	6	4	$7\frac{5}{8}$	$7\frac{7}{8}$	1887	32	6	2	$1\frac{7}{8}$	5
1863	44	9	2	$7\frac{3}{8}$	$5\frac{1}{4}$	1888	31	11	1	$10\frac{3}{4}$	$5\frac{1}{2}$
1864	40	3	1	7	5	1889	29	10	0	$7\frac{7}{8}$	$3\frac{1}{4}$
1865	41	10	2	$10\frac{1}{4}$	$6\frac{5}{8}$	1890	31	11	1	$11\frac{3}{8}$	$4\frac{1}{8}$
1866	50	0	4	$11\frac{1}{4}$	$10\frac{3}{8}$	1891	37	0	2	$11\frac{3}{4}$	$7\frac{3}{4}$
1867	64	6	3	$2\frac{1}{2}$	$9\frac{3}{8}$	1892	30	4	2	6	$4\frac{1}{2}$
1868	63	9	9	$1\frac{5}{8}$	$10\frac{3}{4}$	1893	26	4	0	$10\frac{1}{4}$	$2\frac{3}{4}$
1869	48	3	2	$10\frac{1}{4}$	$8\frac{3}{8}$	1894	22	11	2	$7\frac{1}{2}$	$3\frac{3}{4}$
1870	46	11	4	$2\frac{1}{4}$	$9\frac{3}{4}$	1895	23	1	2	$3\frac{1}{8}$	$4\frac{1}{4}$
1871	56	8	2	2	$5\frac{1}{2}$	1896	26	3	2	$10\frac{1}{4}$	5
1872	57	1	1	$9\frac{1}{4}$	5	1897	30	3	2	$6\frac{3}{4}$	$5\frac{3}{8}$
1873	58	8	2	$10\frac{1}{2}$	$5\frac{3}{4}$	1898	34	0	6	$1\frac{5}{8}$	$10\frac{3}{8}$
1874	55	10	7	$7\frac{3}{4}$	$7\frac{7}{8}$	1899	25	9	0	$10\frac{1}{4}$	3

TABLE IV.—*Average Price of Middling American Cotton at Liverpool. In pence per pound. From Tattersall's Cotton Trade Circular,* 1899.

Year	*d.*	Year	*d.*	Year	*d.*	Year	*d.*
1801	18	1826	$6\frac{3}{4}$	1851	$5\frac{1}{2}$	1876	$6\frac{1}{4}$
1802	16	1827	$6\frac{1}{2}$	1852	$5\frac{5}{16}$	1877	$6\frac{5}{16}$
1803	$12\frac{1}{2}$	1828	$6\frac{3}{8}$	1853	$5\frac{3}{4}$	1878	$6\frac{1}{8}$
1804	14	1829	$5\frac{3}{4}$	1854	$5\frac{3}{8}$	1879	$6\frac{5}{16}$
1805	$16\frac{1}{2}$	1830	$6\frac{7}{8}$	1855	$5\frac{5}{8}$	1880	$6\frac{15}{16}$
1806	$18\frac{1}{4}$	1831	6	1856	$6\frac{5}{16}$	1881	$6\frac{7}{16}$
1807	$14\frac{1}{2}$	1832	$6\frac{5}{8}$	1857	$7\frac{3}{4}$	1882	$6\frac{5}{8}$
1808	22	1833	$8\frac{1}{2}$	1858	$6\frac{7}{8}$	1883	$5\frac{3}{4}$
1809	20	1834	$8\frac{5}{8}$	1859	$6\frac{3}{4}$	1884	6
1810	$15\frac{1}{4}$	1835	$10\frac{1}{4}$	1860	$6\frac{1}{4}$	1885	$5\frac{5}{8}$
1811	$12\frac{1}{2}$	1836	$9\frac{7}{8}$	1861	$8\frac{9}{16}$	1886	$5\frac{1}{8}$
1812	$16\frac{3}{4}$	1837	7	1862	$17\frac{1}{4}$	1887	$5\frac{1}{2}$
1813	23	1838	7	1863	$23\frac{1}{4}$	1888	$5\frac{9}{16}$
1814	$29\frac{1}{2}$	1839	$7\frac{7}{8}$	1864	$27\frac{1}{2}$	1889	$5\frac{15}{16}$
1815	$20\frac{3}{4}$	1840	6	1865	19	1890	6
1816	$18\frac{1}{4}$	1841	$6\frac{1}{4}$	1866	$15\frac{1}{2}$	1891	$4\frac{11}{16}$
1817	$20\frac{1}{8}$	1842	$5\frac{3}{8}$	1867	$10\frac{7}{8}$	1892	$4\frac{3}{16}$
1818	20	1843	$4\frac{5}{8}$	1868	$10\frac{1}{2}$	1893	$4\frac{5}{8}$
1819	$13\frac{1}{2}$	1844	$4\frac{7}{8}$	1869	$12\frac{1}{8}$	1894	$3\frac{13}{16}$
1820	$11\frac{1}{2}$	1845	$4\frac{1}{8}$	1870	$9\frac{15}{16}$	1895	$3\frac{27}{32}$
1821	$9\frac{1}{2}$	1846	$4\frac{7}{8}$	1871	$8\frac{9}{16}$	1896	$4\frac{11}{32}$
1822	$8\frac{1}{4}$	1847	$6\frac{1}{8}$	1872	$10\frac{9}{16}$	1897	$3\frac{29}{32}$
1823	$8\frac{1}{4}$	1848	$4\frac{1}{8}$	1873	9	1898	$3\frac{5}{16}$
1824	$8\frac{1}{2}$	1849	$5\frac{1}{8}$	1874	8	1899	$3\frac{9}{16}$
1825	$11\frac{3}{8}$	1850	7	1875	$7\frac{3}{8}$		

State Monopolies in other Countries.—Interim Report of the Committee, consisting of the late Professor HENRY SIDGWICK (*Chairman*), Mr. H. HIGGS (*Secretary*), Mr. W. M. ACKWORTH, the Right Hon. L. H. COURTNEY, *and* Professor H. S. FOXWELL.

THE Committee have collected the materials for a report the lines of which were under discussion at the time of the Chairman's last illness. It was hoped that he would be able to agree to a report by the end of June; but as he was unable to sign a draft, the Committee have not proceeded further in the matter. They recommend that the Committee be reconstituted under a new Chairman for the purpose of reporting at an early date, and be allowed to retain the unexpended balance of the grant.

Small Screw Gauge.—Report of the Committee, consisting of Sir W. H. PREECE (*Chairman*), Lord KELVIN, Sir F. J. BRAMWELL, Sir H. TRUEMAN WOOD, Major-Gen. WEBBER, Col. WATKIN, Messrs. R. E. CROMPTON, A. STROH, A. LE NEVE FOSTER, C. J. HEWITT, G. K. B. ELPHINSTONE, E. RIGG, C. V. BOYS, J. MARSHALL GORHAM, *and* W. A. PRICE (*Secretary*), *appointed for the purpose of considering whether the British Association form of Thread for Small Screws should be modified, and, if so, in what direction.* (*Drawn up by the Secretary.*)

THIS Committee was appointed at the Ipswich Meeting of the British Association in 1895, to consider repeated complaints that screws of the British Association thread, proposed by the Committee of 1882, obtained commercially, were not satisfactorily interchangeable. It was evident that the difficulty arose from the want of proper gauges, or other ready means of testing screw threads, and the Committee at once took steps to find out how these could be obtained. In a report presented at the Dover Meeting of the Association last year (1899) were described the efforts we had made to secure the production of these gauges, and to make them generally available in a commercial way. We reported that a high degree of accuracy in dimensions, though not in form, had been attained in a small number of specimens submitted to us by the Pratt and Whitney Company; that these were the product of exceptional skill and care; and that they were only obtained after long delay. These gauges were sufficiently good for all practical requirements, and had gauges of the same character been generally available some years before, it is probable that the complaints which led to the appointment of this Committee would never have been made. Taking into consideration the difficulty that had been met in obtaining these gauges; the representations made by the manufacturers of the difficulty in producing them, and of the comparative ease with which a flat-topped thread can be accurately formed; and the fact that such screws are used in foreign countries for the best class of engineering work, we reported that the form of the British Association thread was unsatisfactory, and recommended that the Committee should be reappointed to consider its modification.

A proposal to alter the form of an established and generally satisfac-

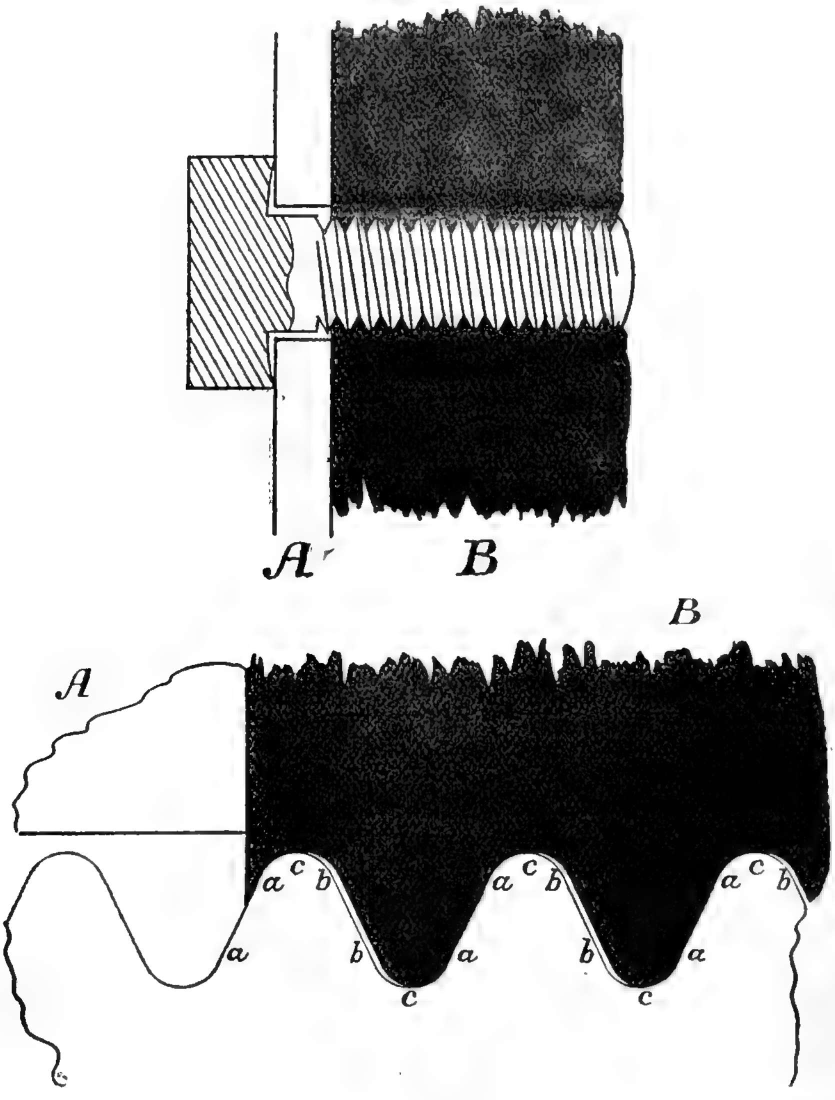
tory system of screw threads may cause some apprehension among users of them, and the Committee, many members of which are intimately acquainted with the trouble and inconvenience incidental to a change of the kind, recognise that very substantial reasons are required to justify it. They think it desirable that the considerations which have led them to make this proposal should be fully stated.

Consideration of the exact cause of the difficulty found in the construction of gauges for the British Association thread showed immediately that it was due to the rounded top and bottom of the thread. There is no difficulty in making any given angle between the straight portions or sides of the generating tool or chaser, but to arrange that these straight lines shall, at definite points, turn smoothly into circular arcs of a given radius is a matter of some difficulty. The difficulty has been met with a good deal of success. The original threads, cut by Mr. Lehmann, and those produced recently by the Pratt and Whitney Company, are admirable specimens of workmanship, especially when the small size of the pieces is considered; and to the careful work done by Mr. Lehmann in the years following 1882, when originating the threads, the success they have achieved is largely due. The production, however, of chasers, even if it can be repeated indefinitely, does not end the difficulty. The hardening of the screws produced by these tools introduces some inaccuracy. They are no longer perfectly straight, perfectly cylindrical, or of perfectly accurate pitch, and the only way to correct them is by grinding. The inaccuracies produced by hardening are not of sufficient importance to affect the use of taps, and in the case of die-plates the errors produced in the diameters are corrected by opening or closing the die; but for gauges corresponding to modern ideas of mechanical accuracy the errors produced by hardening are considerable, and much greater than those found in screws whose forms can be finally obtained by grinding. With the British Association thread this process does not seem to be practicable except perhaps in single specimens, and in this lies the inherent defect of the thread.

A way out of the difficulty is offered by the adoption of a flat-topped thread, but before this can be discussed it is necessary to consider what are the peculiar advantages of the rounded thread, which have brought it into general use, and led to its adoption by the original Committee. The British Association thread was taken with a slight modification directly from Professor Thury's Swiss system, which had been constructed by finding a formula to represent the average existing practice among Swiss clockmakers. Sir Joseph Whitworth formed his system of screws in a similar way by averaging the English engineering practice of his time. It appears that the object in view in both these cases was to regularise existing practice, not to effect a reform; and that an alteration in the form of thread in common use was not contemplated. The same was done in America for the United States thread, so far as the pitches and diameters were concerned, but the form of the thread was determined by Dr. Sellers on general considerations. The origin of the round thread in the British Association system was in the common practice of the Swiss workshops when the rule was constructed. Now, whatever may be the prescribed shape of the thread, it is certain that small screws, produced on screw machines, will have rounded tops, and if a new rule for American threads were constructed from the shapes of ordinary small screws found in the United States, the form obtained would have a rounded top, notwithstanding that they are all supposed to represent the flat-topped Sellers thread. Since

a screw machine tends to produce rounded threads, and the natural course of trade conditions tends to the reproduction of current forms, the common use in Switzerland of screws with rounded threads does not necessarily show that such a form has especial merit, or had originally been deliberately designed. It may be only the result of working conditions. Professor Thury, in defining his thread, chose a form which could be easily produced with fair accuracy, is perfectly efficient, and can be conformed

FIG. 1.



to in practice, but we venture to think it fails to meet other important conditions

To ascertain the conditions which should determine the form of a screw thread, consider the mode of action of a screw holding two pieces together. In fig. 1 the screw serves to hold the plate A to the solid part B, and a small part of the thread is drawn on a larger scale below. The action of the screw depends on the tensile strain due to the pressure

produced over the surfaces *a a*, *a a*, . . . , and the compression produced there by the act of screwing up relieves any pressure over the surfaces *b b*, *b b*, ... Contact and pressure at the points *c c c* . . . depend on the relative diameters of the screw and the tapped hole. The spaces shown in the figure along the surfaces *b b*, *b b*, . . . are of course greater than would occur in a well-fitted screw. Now if the thread may be looked upon merely as a means of supporting the tensional strain on the bolt, without offering much frictional resistance to screwing up, it is clear that this will be most efficiently done if the pressure is evenly supported over the whole of the working surface of the thread *a a*, *a a*, . . ., and within the assigned dimensions of the thread this surface should be as large as possible. Contact and pressure at the points *c*, *c*, . . . depending on the respective diameters of the screw and the tapped hole may interfere with the fair contact of the working surfaces, involve extra resistance to screwing up, and, so far as the support of the tensional strain is concerned, serve no useful purpose. The best design for the thread, in view of its function of supporting the tension, is that which secures most perfectly a continuous working contact over the surface *a a*, *a a*, . . ., and freedom from pressure at other points. These conditions are met best by a thread having straight sides, a flat top, and a clearance space at the top and bottom of the thread such as is shown in fig. 2 (p. 441). The provision of straight sides gives a form to the originating tool which can be produced with more ease and accuracy than one of a curved form, and assists to secure correspondence between the surfaces of the screw and nut: the provision of a flat top gives the largest possible area to the working surface within the given limits of the thread : the provision of a clearance space at top and bottom removes the possibility of any interference with the fit of the working surface by irregularities of form at those points, and avoids unnecessary friction. Screws with straight sides and flat tops are perfectly satisfactory in instrument practice, are employed in France and Germany for the most important engineering work, and are universal in America for work of all kinds, for instrument work as well as heavy engineering work. We understand that the provision of clearance is well recognised in the practice of American and French engineers, who use the Sellers thread, and Mr. Hewitt, at Prescot, gives a very liberal clearance in the screws manufactured by him. The ease with which such threads are originated is a point in their favour, though it would be of small importance if it were shown that the thread is practically defective in other ways.

As regards the reduction of the sectional area of the core by the proposed deepening of the thread, the figures obtained by Messrs. Gorham and Price, corroborated by common experience, show that screws give way under tension by breaking across the core rather than by stripping their threads or those of the nuts ; and it has been urged against the proposal to deepen the thread that it weakens the screw in its already weakest part. The reply to this is that the strength of the screw is really determined by the strength of the core, and that the British Association series is so closely spaced that a screw can always be found whose core is of the required size. Moreover, in well-designed work, screws have so large a factor of safety that a reduction of the section of the core by an amount varying from 8 per cent. in large screws to 12 per cent. in small screws will not generally be a matter of great importance, though it will be remembered that the resistance to torsional fracture varies inversely as the square of the sectional area.

The adoption of a flat-topped thread with a clearance would, we believe, completely obviate the difficulty of producing satisfactory gauges, the question to which the attention of this Committee was originally directed. The construction of these is referred to later in the report. Other elements of the screw have received the attention of the Committee as follows.

Mr. George M. Bond, of the Pratt and Whitney Company, has expressed to the Committee a strong opinion that the angle of 60° employed in the Sellers thread is most suitable for screws because of the ease with which it is formed. Tools can be ground without difficulty, and with great accuracy, to any desired angle, and Mr. Bond's reason appears to the Committee insufficient of itself to justify a change in practice. Considering, however, the extent to which screws of the Sellers form are employed in foreign engineering work, the Committee desired to obtain some evidence of the exact value of the particular angle of 60°, since, if this angle were found to possess a great advantage over the angle of $47\frac{1}{2}°$, the adoption of the Sellers thread would have the additional recommendation of bringing the small screw practice into line with an already extensive engineering practice, while giving effect to the conclusions already reached by the Committee of the desirability of clearance and a flat-topped thread. Some experiments on lines suggested by Mr. Crompton have been carried out by Messrs. J. Marshall Gorham and W. A. Price, and their results are printed as an appendix to this report. They concluded that an angle of $47\frac{1}{2}°$ is better for screws than an angle of 60°, on the ground that it offers much less frictional resistance to screwing and unscrewing on a given tensional load, and the general tendency of this observation is corroborated by the practice of using a thread for the leading screws of lathes, the screws of carpenters' clamps, and of screw jacks, in which the working surface is perpendicular to the axis of the screw. Another consideration leads us to think it undesirable to adopt an angle of 60°. The advantage of bringing small screw-practice into line with that of foreign engineers will only be fully gained if their rule for the size of the flat top of the thread is also adopted. This rule gives a maximum possible clearance of ·108 pitch when the thread is cut to a perfectly sharp V at the bottom. This clearance would be sufficient but tools with perfectly sharp points are maintained with difficulty, and it would not generally obtain. A tool of $47\frac{1}{2}°$, ground to give a clearance of ·1 of the pitch, has a flat at the point one-seventh of the pitch wide. For small screws Professor Thury's angle of $47\frac{1}{2}°$ had the same sanction of practice among clockmakers as a larger angle had among engineers when it was adopted by Dr. Sellers; and though it is often difficult to assign exact reasons for the particular practice of practical men, yet it cannot be disregarded unless the reasons for its use are quite clear, and are shown to be insufficient. We see no sufficient reason to change the present angle of $47\frac{1}{2}°$, especially as a change of angle would make existing stocks and tools altogether useless in conjunction with the existing form.

The existing series of pitches and diameters, with their designating numbers, is generally approved, and the Committee have received no suggestion that it is otherwise than satisfactory.

Thus far it has been assumed that, given the necessary tools, all forms of thread can be produced with the same ease. This, however, does not apply to the small screws used in watches, which are produced by turning the blanks into a hard die without cutting edges. In such a process

great force would be required either to squeeze the metal into sharp re-entrant angles, or to make it flow past sharp corners. On this point Mr. C. J. Hewitt writes to the Committee respecting the proposed alteration of the British Association thread : ‘A die of this operating character for screws flatted top and bottom soon loses its contour, and needs constant replacement; and in addition my experience leads me to believe that it requires more force than a rounded thread ; therefore it sets up more torsional strain of the metal, a factor of great moment where such

FIG. 2.

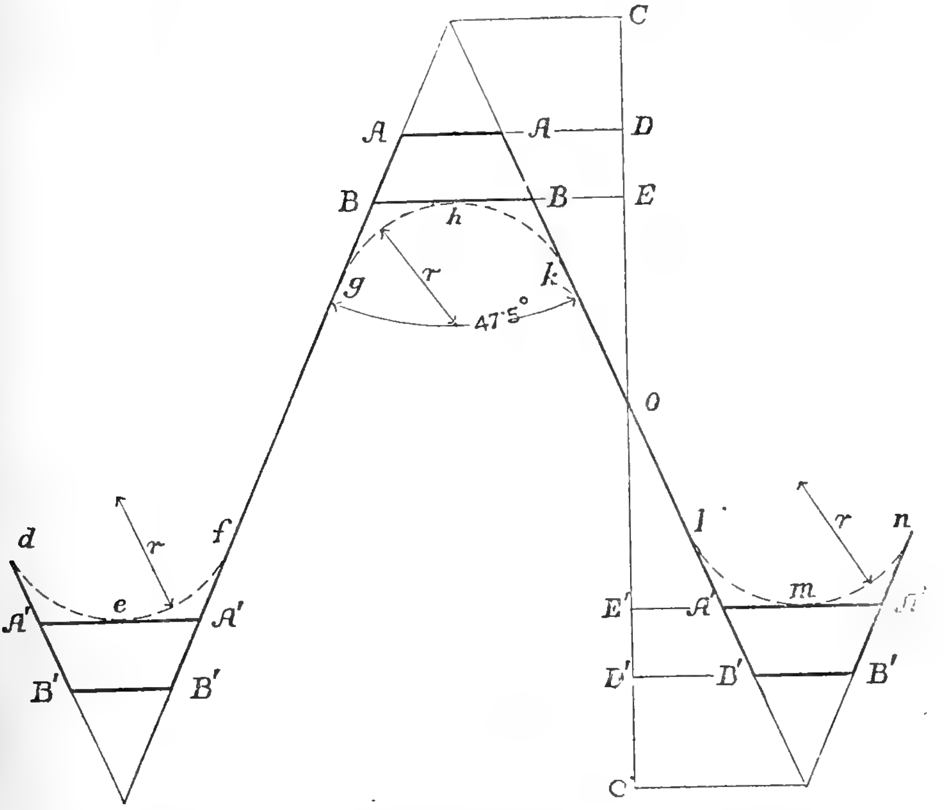


TABLE OF DIMENSIONS.

em = pitch.	EE′ = ·6 pitch.	AA = ·149 pitch.
CC′ = 1·14 pitch.	BOA′ = ·655 „	BB = ·238 „
DD′ = ·8 „	kOl = ·115 „	r = ·182 „

small diameters are being produced, breakage in the dies being a constant source of trouble even at the best.’ In the same letter Mr. Hewitt explicitly approves the proposals of the Committee for the larger threads, both as regards the flat top and the provision of clearance. Mr. Hewitt’s experience at the Prescot watch factory is so large, and his knowledge of the manufacture of watchmakers’ screws is so intimate, that the other members of the Committee have no hesitation in accepting his suggestion to divide the present series into two sections. The large section, consisting of what may be called instrument-makers’ screws, from No. 0 to No. 11, includes screws from 6 mm. to 1·5 mm., or in English measure from $\frac{1}{4}$ inch to ·059 inch. The small section, from No. 12 downwards, consisting of watchmakers’ screws, includes screws below 1·5 mm.,

or in English measure below ·059 inch. The Committee propose to modify the form of thread of the screw of the large section only.

The above considerations lead the Committee to propose to replace the present form of thread of screws from No. 0 to No. 11 inclusive by the form shown in fig. 2.

Here the line $A' A A$ . . . represents the outline of the nut, $B' B B$ . . . of the screw ; and $d e f$ . . . is the outline of the present British Association thread. It will be observed that the flat part of the side, or the working surface, is increased by nearly 60 per cent. Accurately formed screws of this pattern for special purposes can be cut on the lathe with much greater ease than those with a rounded thread. The screw is cut with a single-point tool from a cylinder, and in the larger sizes the nut can be cut with a single-point tool from a cylindrical hole. The difficulty of forming chasers of a complicated form is entirely avoided. These observations apply equally to the construction of taps and plates, and of gauge-pieces. Given that the pitch of the screw and the angle of the thread are accurate, and the sides straight, the fit of the screw in a correct gauge is determined by the length of the diametral line terminated by the inclined sides of the thread, and this dimension is called *the effective diameter of the screw*. If this dimension is the same in the screw and the nut, they will fit without shake independently of the exact values of the external and internal diameters, or of the exact form of the ends ; and the lengths of the effective diameters of screws and nuts are definite numerical measures of their fits one with another. The point which it is important should be right is the straight between A′ and B in both nut and screw. The nut must not pass A′, nor the screw pass B ; but so long as the nut is cut as far as B or farther the shape of the excess does not matter. The same thing holds with the screw at A′, but here excessive clearance is objectionable because it weakens the core of the screw.

In constructing plug-gauges for testing nuts the straight sides of the thread can be corrected after hardening by grinding with a lap, and this process corrects at once the irregularities of pitch and angle, and is continued till the effective diameter is reduced to the desired value. The top of the thread, being cylindrical, presents no difficulty. The form of the bottom of the thread is immaterial, since the clear hole in the nut is most conveniently tested with a cylinder plug-gauge. In the specimens submitted to us last year by the Pratt and Whitney Company this cylinder was constructed in one piece with the screwed plug.

In ring or nut gauges for testing screws a slit is cut through the tapped hole, and closed with a screw. The hole can be polished by a corresponding screwed piece, but could only be corrected by grinding by the use of very refined appliances. After polishing the slit is closed to fit a prepared screwed plug, and the clear hole brought to its correct value with a lap. The process is not so satisfactory as with a plug-gauge, but the pieces which the ring is designed to test can be satisfactorily measured in other ways, so that the gauge is of less importance.

The effective diameter of a screw is readily measured in a micrometer gauge between a conical point and a V notch, both having an angle of $47\frac{1}{2}°$. An instrument of this kind constructed for 60° is figured in toolmakers' catalogues.

Ordinary taps for nuts or for the working holes in larger pieces will be different in form from the screws, and different from the taps employed to make dies or screw-plates. The ordinary dies or plates in a workshop

used for making screws will not be suitable for making taps. In small workshops this may sometimes cause mistakes, but in shops having a separate tool-room this extra specialisation should present no difficulty.

Objections have been raised to the above proposal on three grounds.

It has been represented to us that in finely fitted work the screws should fit their holes perfectly and all over, and that the existence of a clearance gap all round the edge of the thread is inconsistent with a high standard of workmanship. This objection is evidently to some extent a matter of opinion, and it is always possible to use taps of the same form as the screws, so that the screws will fit the taps all over as in a non-clearance system.

It has been objected that the introduction of the proposed system will seriously interfere with existing stocks of screws and the repairs of existing instruments. In fig. 2 it is shown that the new thread differs from the old one by the addition of the small corners, $g\,B\,h$, $h\,B\,k$, to the screw, and $d\,A'\,e$, $e\,A'\,f$, to the nut. In making screws and nuts with dies and taps, these corners will always be rounded off to some extent, though the re-entrant angles at $A\,B'$ will be as sharp as the tool which makes them. In some screws and nuts prepared experimentally to test this point, the outer edges of the thread were fairly rounded, and they were perfectly interchangeable with the B.A. screws of an existing manufacturer's stock. The Committee believe that screws made to the proposed new thread will, owing to the inevitable rounding, be interchangeable with existing stocks in a great majority of cases, and that only in cases where great care has been taken to work closely to the old standard will any difference be noticed.

It has been objected that the proposed thread is unsuitable for such work as bicycles and small arms which are subject to violent concussion and vibration, whereby the screws are liable to be shaken loose and to drop out; and the case of alternating current arc lamps has been mentioned to the Committee as one in which the same thing is liable to occur. Mr. O. P. Clements of the Birmingham Small Arms Company contributes a paper to the Mechanical Section on the practice of his firm in the manufacture of screws for bicycle parts, for which it is found necessary to use rounded threads fitting very closely all over. It is clear that no one form of thread can be suitable for all purposes, and we have direct evidence that the form of thread we propose does not fail in instrument work in the way Mr. Clements anticipates that it would do in bicycle work.

We beg to report that the system of screw threads recommended by the British Association for the use of instrument makers, and known as the British Association screw threads, should be modified in the following way for all screws from No. 0 to No. 11 inclusive.

For screws.—That the designating numbers, pitches, outside diameters, and the common angle of $47\frac{1}{2}°$ remain unchanged; but that the top and bottom of the thread shall be cylindrical, showing flats in section, and that the depth of the thread shall be increased by one-tenth of the pitch, the diameter of the solid core being, in consequence, diminished by one-fifth of the pitch.

For nuts.—That the designating numbers, the pitches, the diameters of the clear holes, and the common angle of $47\frac{1}{2}°$ remain unchanged; but that the top and bottom of the thread shall be cylindrical, showing flats in section, and that the depth of the thread shall be increased by one-tenth of the pitch.

The appended table gives the pitches and diameters of the different threads modified in accordance with this recommendation.

Table of the pitches and diameters of the British Association thread under the rule proposed above.

No.	Pitch		Screw				Nut			
			Outside diameter		Inside diameter		Outside diameter		Inside diameter	
	Millimetres	Mils	Millimetres	Mils	Millimetres	Mils	Millimetres	Mils	Millimetres	Mils
0	1·0	39·4	6·0	236·2	4·6	181·1	6·2	244·1	4·8	189·0
1	·9	35·4	5·3	208·7	4·04	159·1	5·48	215·8	4·22	166·2
2	·81	31·9	4·7	185·0	3·566	140·4	4·862	191·4	3·728	146·8
3	·73	28·7	4·1	161·4	3·078	121·2	4·246	167·2	3·224	126·9
4	·66	26·0	3·6	141·7	2·676	105·4	3·732	146·9	2·808	110·6
5	·59	23·2	3·2	126·0	2·374	93·5	3·318	130·6	2·492	98·1
6	·53	20·9	2·8	110·2	2·058	81·0	2·906	114·4	2·164	85·2
7	·48	18·9	2·5	98·4	1·828	72·0	2·596	102·2	1·924	75·7
8	·43	16·9	2·2	86·6	1·598	62·9	2·286	90·0	1·684	66·3
9	·39	15·4	1·9	74·8	1·354	53·3	1·978	77·9	1·432	56·4
10	·35	13·8	1·7	66·9	1·210	47·6	1·77	69·7	1·280	50·4
11	·31	12·2	1·5	59·1	1·066	42·0	1·562	61·5	1·128	44·4

In order to give practical effect to our recommendations we desire to obtain a set of the proposed screws, with tools and gauges, for comparison with the present ones. We shall thus be able to exhibit in a concrete form the character of the thread, and also to show how far screws made with the new tools are interchangeable with the existing stocks. We recommend that the Committee shall be reappointed for this purpose with a grant of 50*l*.

APPENDIX.

Report of Experiments on Screw Threads made by J. MARSHALL GORHAM *and* W. A. PRICE.

The object of these experiments was to determine the relative advantages of different angles for the threads of small screws, and two questions were proposed for trial.

1. Which angle gives the greatest frictional torque to resist unscrewing?

2. Which angle gives the greatest resistance to the tearing of a steel screw out of a brass plate or nut?

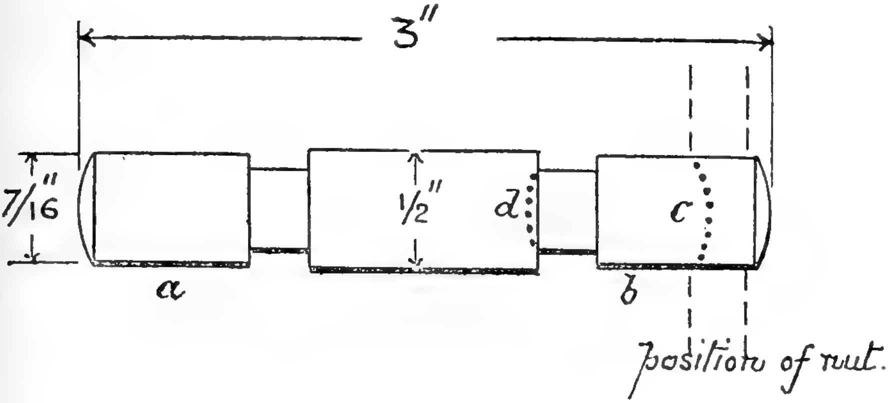
To answer these questions, six pieces, of the form of fig. 3, were made of steel. On one end, *a*, of each a thread was cut which was the same in every case, and was used only for the purpose of connecting the pieces in the testing-machine. The threads to be compared were cut on the ends *b*. Three kinds of thread were tried, two pieces being made of each kind of thread.

The mode of trial is shown in fig. 4. A pair of these steel pieces, A A, having threads of the same kind at the ends *b b*, were tightly screwed

by the ends *a a* into a sleeve F, so that they could not be unscrewed by the forces employed in the test. On the ends *b b* were placed brass nuts B B, supported on steel collars C C, which rested in spherical seats in the brass pieces D D. These last pieces D D were screwed into E E, the cast-iron terminal blocks of the testing-machine.

Two experiments were made in each case.

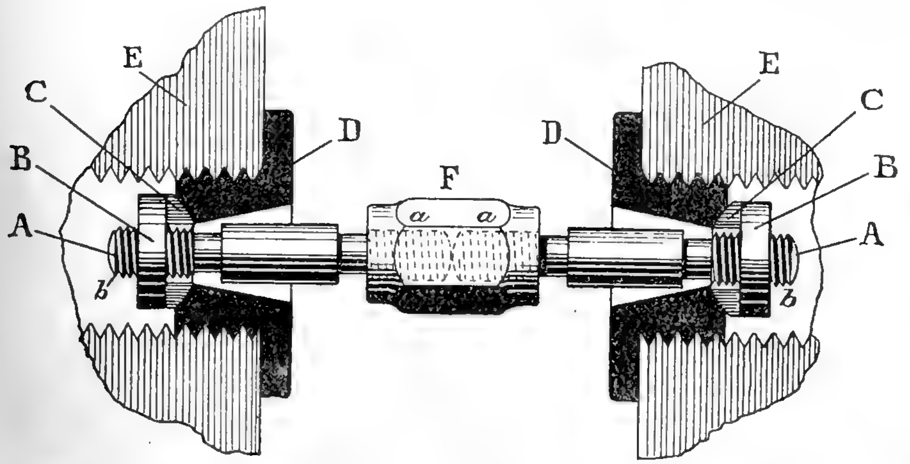
FIG. 3.



1. With a steady pull on the specimens the torque required to turn both screws simultaneously in their nuts was measured. This was ascertained by means of a small spring balance acting by a lever on the hexagonal sleeve F.

2. The pull of the testing-machine was then steadily increased until one of the screws was pulled through the nut.

FIG. 4.

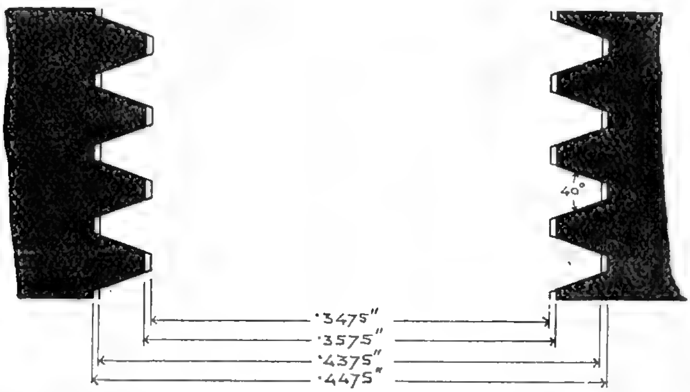


The screwed pieces A A were turned out of tool steel, bright drawn rods of clockmakers' silver steel, $\frac{1}{2}''$ diameter. The main object of the experiments being to find the force required to shear the thread out of the nuts B B by screws of given form, any deformation of the screw itself had to be avoided. The *b* ends of the steel pieces were accordingly water-hardened and let down to a spring temper. In the course of testing, one out of each pair of steel screws broke at the point where it entered the

brass nut, at a strain much below the calculated breaking strain. The form of the fracture was in every case that of the dotted line *c*, shown in fig. 3. Professor Unwin, to whom this point was submitted, supposes that this has no bearing on the strength or weakness of the particular forms of thread used, but was due to internal strains in the steel produced by the water-hardening, and to a slight bending force acting with maximum effect at the point where the screw enters the nut. The spherical seats of the collars C C will not, he points out, wholly prevent the occurrence of this force. He suggests that had the screws been hardened in oil this probably would not have happened. The sectional area of the cores of the screws was ·095 square inch, and the breaking strain was expected to be about 13,500 lb. Those that broke where they entered the nut broke at 5,600 lb. (60° screw), 5,860 lb. (50° screw), and 5,330 lb. (40° screw) respectively. In a subsequent test one of them broke along the line *d* (fig. 3) at 10,280 lb. Fortunately, in every case a sufficient length of the screw was left after the accident to put on another nut, and in each case a satisfactory result was obtained in a subsequent trial, the screws being drawn through the nuts without being themselves broken.

The forms of the screws tested are shown in figs. 5 and 6. The

FIG. 5.



diameters, both at the top and the bottom of the thread, were the same in all the screws, and also in all the nuts. The screw-threads were in all cases flat-topped, with slightly rounded, but nearly flat, bottoms. The pitch of the screw was the same in every case, 16 to the inch. The three threads had angles respectively of 40°, 50°, and 60°. Each screw was cut with a single point tool, ground to the correct angle from a cylinder previously turned to the correct diameter. The nuts were cut with single point inside turning tools, also accurately ground, in a cylindrical hole previously bored to the correct diameter.

The outside diameter of each screw was $\frac{7}{16}$ inch (·4375); and the inside diameter of each nut was ·3575 inch. A clearance of ·005 inch was given at the top and bottom of the thread in every case.

Fig. 5 shows the form of the screw and nut, having an angle of 40°, and the dimensions which are figured are the same in each of the other two cases.

Fig. 6 gives the outline of the contact surfaces of the screw and nut in each of the three cases. In this figure the dimensions are figured in thousandths of an inch.

The dimensions employed for these screws were chosen as sizes, which,

while not extravagantly outside those of the screws to which the data are to be applied, provide quantities convenient for measurement with a micrometer gauge, and for the testing-machine.

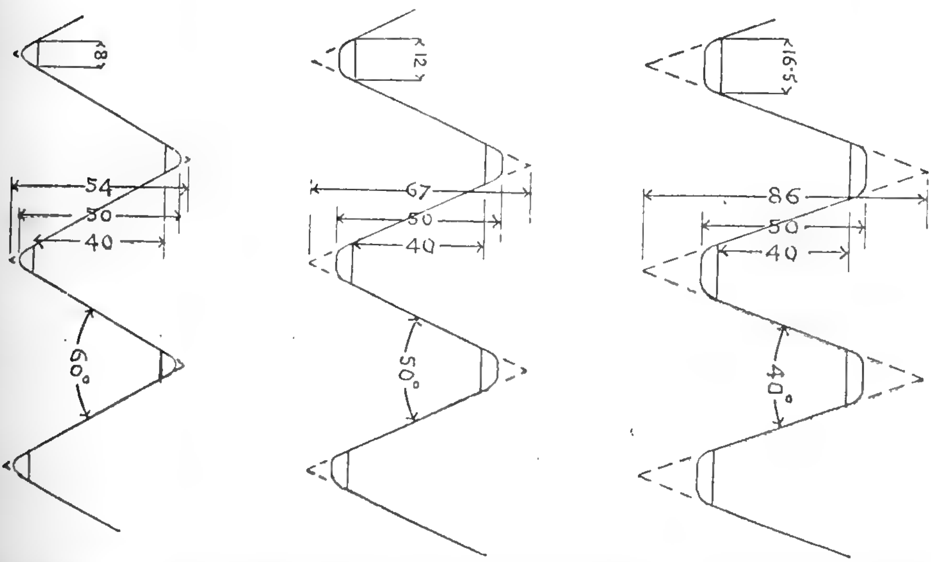
The following results were obtained :—

A.—Torque required to turn a pair of the screws in two nuts, each ·226 inch thick (3·6 threads) drawn apart with a strain of 1 ton.

Angle of thread.	Torque required.	
40°	11 foot pounds	$11 \times \cos 20° = 10{\cdot}34$
50°	13 ,, ,,	$13 \times \cos 25° = 11{\cdot}7$
60°	18 ,, ,,	$18 \times \cos 30° = 15{\cdot}6$

It will be observed that frictional resistance to unscrewing increases with the angle of the thread much more rapidly than in proportion to the

FIG. 6.



increased surface pressures due to the oblique thrust. The above figures, from specimens black from the hardening process, are higher than one obtained from a screw with a bright surface in a preliminary experiment, by about 90 per cent.

B.—Pull on the screw required to shear the thread out of a brass nut ·226 inch thick (3·6 threads) cut from flat drawn strip.

Angle of thread.	Force required to shear thread.	Area of thread sheared.	Shearing force per square inch.
40°	5,500 lb.	·2275 sq. in.	24,160 lb.
50°	6,220 lb.	·250 ,,	24,880 lb.
60°	6,590 lb.	·270 ,,	25,200 lb.

In this table the area of the thread sheared is obtained from a measurement of the space left for the thread of the nut between the successive threads of the screw, so that this area is less as the screw thread has a wider top.

C.—Pull required to shear the thread away from a cast brass nut ·250 inch thick (4 threads).

Angle of thread.	Force required to shear thread.	Area of thread sheared.	Shearing force per square inch.
40°	(1) 4,890 lb.	·253 sq. in.	
	(2) 4,760 lb.	„ „	
	mean 4,825 lb.		19,080 lb.
50°	(1) 5,400 lb.	·2775 „	
	(2) 5,130 lb.	„ „	
	mean 5,265 lb.		18,960 lb.
60°	(1) 5,500 lb.	·300 „	
	(2) 5,600 lb.	„ „	
	mean 5,550 lb.		18,500 lb.

In these experiments only one screw and one nut were used in each pull, the connection to the other side of the hexagonal sleeve being made with a $\frac{1}{2}''$ steel bolt. Two nuts of each size were sheared. In this case no measurements were taken of twisting torque.

D.—The screw of 60° was tested on a brass nut ·250 inch thick (4 threads) made from hard drawn rod.

1. Screw broke at 10,280 lb. along line *d*, fig. 3.

2. Another similar screw sheared the nut at 10,820 lb. Area sheared ·300 square inch. Shearing force per square inch 36,070 lb.

In all cases the nut was sheared along the outside surface of the screw, not at the bottom of its own thread, so that the hole left was a tight fit for the screw which had been pulled through.

These figures suggest the following conclusions :—

1. That the angle of a flat-ended thread has little effect on the resistance of the nut to shearing, except so far as it affects the area of the surface to be sheared ; and the advantage possessed by the 60° thread over the others is only due to the fact that its flat top is narrower than theirs, and the base of the nut thread correspondingly wider. From analogy with the relative behaviour of sharp and blunted dies used in stamping, it seems that a flat-topped thread with sharp edges should shear a nut more easily than a rounded thread.

2. That the strength of the thread of the nut, compared with that of the core of the screw, is such that generally in practice nuts are stronger than their screws.

For example, a flat-ended thread of the dimensions of No. 0 B.A. of 40-ton steel will break before it strips the thread from a hard drawn brass nut $\frac{1}{8}$ inch thick. So a similar screw of the dimensions of No. 6 B.A. of the same steel will break sooner than strip a brass nut $\frac{1}{12}$ inch thick.

With steel nuts the nut will generally be very much stronger than the screw.

3. Considering (*a*) that the holding strength of a screw bolt is generally determined (and that especially in small screws) by the resistance of the bolt under tensile stress ; and (*b*) that, as ascertained by Professor Martens, the resistance of a screw bolt to fracture is very largely diminished by simultaneous torsional stress ; it is desirable that such resistance as may be desired to tightening or loosening a bolt should be obtained by means of the friction of the under surface of the nut or screw head, and that the friction of the threaded surface of the screw itself should be as small as possible. From this point of view experiments A indicate that an angle of thread of 40° or 50° is to be preferred to an angle of 60°, and that especially so in the case of small screws.

The authors of this Report are under a great obligation to Professor T. Hudson Beare for his kind assistance in ascertaining the breaking strains of the specimens.

The Micro-chemistry of Cells.—Report of the Committee, consisting of Professor E. A. SCHÄFER (*Chairman*), Professor E. RAY LANKESTER, Professor W. D. HALLIBURTON, Mr. G. C. BOURNE, *and* Professor A. B. MACALLUM (*Secretary*). (*Drawn up by the Secretary*)

THE work of the Committee was directed along the following lines :—

1. *The Localisation of Phosphorus in the Cell.*—In this investigation a wide range of animal and vegetable forms was employed as material, and solutions of molybdate of ammonia in nitric acid were used to localise the phosphorus as a phospho-molybdate compound, the distribution of the latter being revealed after the preparations were treated with solutions of phenylhydrazine hydrochloride. The results show that the element exists in cells in at least five states of combination : (*a*) As a nuclein or nucleo-proteid in which the phosphorus is firmly combined in both cytoplasm and nucleus. (*b*) As a derivative (nucleinoid) of nuclein or nucleo-proteid, in which the phosphorus is much less firmly combined. Examples of this are found in smooth muscle fibre in the dim bands of striated muscle fibre, in the substance constituting the zymogen granules in secreting glands, and in the outer limbs of the retinal rods and cones. (*c*) As an inorganic metaphosphate dissolved in the cytoplasm of some cells, and apparently derived from *a* and *b*. (*d*) As lecithin, which is present in every cell, and markedly in nerve tissue. (*e*) As an inorganic orthophosphate in the tissues of various organs, *e.g.* liver, spleen, kidney, intestinal mucosa, placenta, &c. In the demonstration of the occurrence of these compounds of phosphorus, the length of time required to demonstrate their presence is an important factor ; and, further, the metaphosphate and orthophosphate may be removed from a preparation in a couple of hours by the action of dilute nitric acid, while lecithin may be extracted by repeated treatment with hot alcohol. By making preparations of cells and tissues with the molybdate method, both before and after the action of dilute nitric acid, as well as before and after extraction with alcohol, it was found possible in every case to ascertain the occurrence of one or all of these five classes of compounds in a cellular element.

This investigation has given a very large number of results which are of too detailed a character to be referred to specially here, and references to which are now being incorporated in a special paper for publication. One generalisation from these observations may, however, be in place here. The organic, usually iron-free, compounds of phosphorus, which are almost universally present in the cytoplasm of nucleated cells, bear a derivative relation to those which are in the nucleus, and which contain 'masked' iron, while in non-nucleated organisms the compounds of iron and phosphorus are found in the cytoplasm in all cases in a diffused form, but in some also as granules (Cyanophyceæ and the Yeasts). From the chemical point of view the nucleus is therefore an organ for containing the iron-holding nucleo-proteids, and it is therefore an organ of secondary and later origin in the development of the primal cell organism.

2. *The Relation of the Iron to the other Elements in the Chromatin or Nuclein Molecule.*—In this the point to be determined was whether the iron atom is directly united to a carbon atom, as it presumably is in

hæmoglobin, which is derived from chromatin, or, as Ascoli[1] claims, to the phosphorus as a polymetaphosphate of iron. For this purpose quantities of iron holding nuclein, prepared from lamb's testicles, were subjected to the action of water at 160° to 170° C., under pressure for four to eight hours. This brings about a decomposition of the nuclein, setting free the metaphosphoric acid as the ortho acid. It was found that in the first four to six hours nearly all the phosphorus of the compound appears in solution as ortho-phosphoric acid, with traces of iron, the rest of the iron appearing to be still in organic combination in other decomposition products either in solution or undissolved. If the iron were combined with the meta-phosphoric acid it ought to appear as ferric phosphate, which is soluble in the presence of ortho-phosphoric acid. In the absence of this result it must, therefore, be held that the iron is directly associated in the nuclein molecule with some other element, probably carbon.

3. *On the Localisation of Oxidising Enzymes in the Cell.*—For this purpose unicellular algæ, and more particularly *Spirogyra*, were used. The tests for these enzymes are not sufficiently delicate to enable one to detect their distribution micro-chemically, but it was found that on subjecting masses of the living *Spirogyra* threads washed with distilled water to various degrees of pressure in a specially made hydraulic press one obtained solutions of the various ferments the position of each of which in the cell is approximately determinable by the pressure used. For example, with an initial low pressure the fluid or solution expressed was largely, if not wholly, from the spaces in the cell surrounding the chromatophore and the stellate cytoplasmic mass which contains the nucleus, while with a considerably greater pressure one obtains cytoplasmic and nuclear fluids in a second solution, and with the maximum pressure the cytoplasmic and nuclear structures, but not the chromatophore, are disintegrated to a certain extent and pass into the fluid expressed as suspended material, which, if kept in this condition for three or four days, partially dissolves. This forms the third solution. In testing for the occurrence of oxidising enzymes in these solutions various readily oxidisable reagents were used as indicators, but the one which gave results most to be relied upon was guaiacum in absolute alcohol, a drop of which added to a solution of an oxidising enzyme results in the production of a blue solution in from a few minutes to half an hour. It was found that an oxidase is present in solution No. 1 in considerable quantities, but sparingly in No. 2, and it is not demonstrable in No. 3. In the first solution an aëro-oxidase occurs in small quantities, that is, an oxidase which is active only in contact with air. Traces of an aëro-oxidase were found in the second solution, but not in that obtained with the maximum pressure. In the last, however, was found abundant evidence of the presence of a peroxidase, that is, of an oxidase which renders guaiacum solutions (emulsions) blue only in the presence of hydrogen peroxide. This same solution also was found to contain a catalase (Loew), that is, a ferment which liberates oxygen from hydrogen peroxide, but which does not oxidise guaiacum emulsions. From such experiments it would appear that the peroxidase and catalase are very intimately associated with the protoplasmic and nuclear structures of the cell while the oxidase and aëro-oxidase are in media external to the protoplasm. It is important to note that the chromatophore does not yield an oxidising ferment or catalase.

[1] *Zeit. für Physiol. Chemie*, vol. xxviii, p. 426.

4. *On the Micro-chemistry of Oxyphile Granules*, by Dr. J. J. Mackenzie.—Observations on the eosinophilous cells of the bone marrow of the cat and frog and on the same variety of cells from the cœlomic cavity of the frog show that although there is obtained in the granules a distinct iron reaction with ammonium sulphide when the preparation is kept in a mixture of this reagent and glycerine at a temperature of 55–60° C. for 7 to 10 days the reaction is not nearly so marked as in the nuclear chromatin of the same cells and is less readily demonstrated. The method in which acid alcohol is used to liberate the iron from its 'masked' condition, and hæmatoxylin to demonstrate the liberated iron, does not reveal the iron in these granules ; at most with this method one finds a slight reaction in the perigranular protoplasm, but not in the granules themselves. These granules give a reaction for phosphorus when they are treated with a nitric acid solution of ammonium molybdate for some hours, and subsequently with a solution of phenylhydrazine hydrochloride. The reaction is much more marked than that in the nuclear chromatin. It is evident from these observations that the substance forming the eosinophilous granules is a nucleo-proteid containing traces of iron, and that it is probably a derivative of nuclear chromatin.

5. *On the Micro-chemistry of the Nucleus*, by Dr. F. H. Scott.—It was found that the non-chromatin and non-nucleolar portions of the nuclei in gland cells which constitute the *lanthanin* of Heidenhain and the *œdematin* of Reinke, though soluble in gastric juice, give evidence of the presence of 'masked' iron and organic phosphorus in small proportions. Similar evidence was obtained in the case of the non-nucleolar and non-chromatin portions of the nuclei of nerve-cells. It is probable that lanthanin or œdematin, while unlike a nucleo-proteid in some respects, is a closely related compound.

During the past year the following papers, including observations on the micro-chemistry of cells made during the last two years, were published :—

1. *On the Structure, Micro-chemistry, and Development of Nerve Cells, with Special Reference to their Nuclein Compounds.* By Dr. F. H. Scott, 'Trans. Can. Inst.,' vol. vi. p. 405, and University of Toronto Studies, Physiological Series, No. 1.
2. *On the Cytology of Non-nucleated Organisms.* By Professor A. B. Macallum, 'Trans. Can. Inst.,' vol. vi. p. 439, and University of Toronto Studies, Physiological Series, No. 2.

Summary of Dr. Scott's Paper.

The Nissl granules were found to contain 'masked' iron and organic phosphorus and to be unaffected by treatment with artificial gastric juice. They are therefore constituted of a nucleo-proteid in many respects allied to chromatin. It differs, however, from the nuclear chromatin which is basophile and from the substance forming the oxyphile centre of the nucleoli and the material diffused through the nuclear cavity in fully developed nerve-cells. The latter substance also contains organic phosphorus and 'masked' iron, and is digestible in artificial gastric juice. These three nucleo-proteids are derived from the original kinetic chromatin of the neuroblast, and the substance forming the Nissl granules is the only nucleo-proteid of the three that diffuses from the nucleus. In some forms this diffusion does not take place in the fully developed cell, or does so

only to a very slight extent. In this case few or no Nissl granules are found; a condition which is very much like that observed in the not fully developed nerve-cell, and therefore embryonic. This condition is markedly illustrated in the nerve-cells in Caudate Amphibia.

Summary of Professor Macallum's Observations.

In the Cyanophyceæ the cell, which is non-nucleated, contains two zones, a central and a peripheral. The latter contains the colouring matter, and in its vesiculated cytoplasm there is a compound which gives evidence of containing traces of organic phosphorus and 'masked' iron. On the other hand, the central body gives marked reactions for these two elements which are united in a compound diffused throughout its structure. This compound stains with hæmatoxylin like chromatin, and as it resists digestion it is probably chromatin. An iron-holding nucleo-proteid constitutes the red granules of Bütschli, but it differs from chromatin in that it is digestible with artificial gastric juice. Another variety of granules, called 'cyanophycin' granules, found only in the peripheral layer, are formed of proteid free from iron and phosphorus. The only substance in the Cyanophyceæ which resembles fully the chromatin of the cells of higher organisms is that holding iron and phosphorus and diffused in the central body.

In the yeast all the iron and phosphorus, in addition to being diffused throughout the cytoplasm, are also localised in small granules and corpuscles which have been held to be nuclei and nucleoli by various observers. The substance which constitutes these and that in which are combined the iron and phosphorus diffused through the cytoplasm are different from the chromatin of higher organisms, in that they are soluble in artificial gastric juice; but they are the only chromatin-like substances present in the yeast-cell.

In *Beggiatoa* the compounds containing 'masked' iron and organic phosphorus are uniformly diffused throughout the cytoplasm, and when granules which stain with hæmatoxylin occur they also are found to contain iron and phosphorus in a corresponding form of combination.

The Committee ask to be reappointed, with the addition of Professor J. J. Mackenzie, of Toronto.

Comparative Histology of Suprarenal Capsules.—Report of the Committee, consisting of Professor E. A. SCHÄFER (*Chairman*), Mr. SWALE VINCENT (*Secretary*), *and* Mr. VICTOR HORSLEY.

DURING the past year several points in connection with the comparative histology of the suprarenal capsules have been reinvestigated, and during the investigation several subsidiary inquiries have arisen, such as the histology of the pituitary body and some points in its physiology, the physiological actions of extracts of nervous tissues, &c. The results of these investigations are given at length in papers published during the year in the 'Journ. of Physiol.' and in the 'Brit. Med. Journ.' See also 'Anat. Anz.,' Bd. xviii. S. 69, 1900.

The Comparative Histology of Cerebral Cortex.—Report of the Committee, consisting of Professor F. GOTCH (*Chairman*), Dr. G. MANN (*Secretary*), *and* Professor E. H. STARLING. (*Drawn up by the Secretary.*)

SINCE the last report three complete series of sections have been made of the central nervous system of the bonnet monkey—viz., (1) transverse sections from the thalamus to and including the second dorsal nerve, from material fixed in Mann's picro-corrosive formaldehyde; (2) a coronal series through the lower part of the medulla and up to and including the eighth cervical segment (fixed in picro-corrosive formaldehyde); (3) a Weigert series extending from the fillet decussation to the dorsal cord.

The reason for investigating these regions was to ascertain whether so-called motor-cells differed from 'sensory' ones in any definite structural characteristics. Nothing was discovered by which one kind of cell could be distinguished from the other, and it has become evident that Nissl's classification is a purely artificial one. All cells show a distinct fibrillation, and the basophil 'Nissl-substance' lying between the bundles of fibrils.

Motor cells, as a rule, have a greater development of the dendra, and, in consequence, the fibrils coming from these processes in coursing through the cell break up the available space in a regular, uniform manner, and hence there results a more regular arrangement of the basophil granules. In sensory cells, on the other hand, because of the special development of one or two dendritic processes one frequently notices on that side of the nucleus looking towards the biggest dendron a pyramidal (in section triangular) area, occupied by non-differentiated plasm, and formed by the divergence of the fibrils coming from the big dendron and sweeping round the nucleus. In these cells, as seen most characteristically in the *Locus cœruleus*, *Substantia nigra*, lateral horns of the spinal cord and the antero-mesial visceral group of cells, Nissl's granules form relatively coarse aggregations towards one side of the cell. At one time it was thought that a certain appearance first described by Mann in 1894 [1] in the occipital lobe of the rabbit, since then rediscovered by Roncorini and discredited by Levi—viz., the presence of crescentic bodies on one side of the nucleus—would allow of a ready distinction between nerve-cells in the cerebrum and those found in the lower centres. This, however, was found not to be the case, for the same appearance is seen throughout the whole length of the spinal cord right down to the coccygeal portion. The examination of the dorsal and lower regions of the cord was made possible through the kindness of Miss M. Purefoy FitzGerald, who placed at our disposal the complete series of sections she is tabulating at Oxford.

As to the real existence of these crescents there cannot be the slightest doubt, for Levi's suggestion that we are dealing with a folding of the nuclear membrane is readily disproved by making transverse sections of the cells in the Cornu Ammonis at right angles to their long axis, and staining them by Mann's eosin-toluidin-blue method, when these crescents in question appear one in each nucleus as distinct swellings in the nuclear membrane, while the latter is not stained at all. In addition to the common crescentic type one may frequently see in surface views branches

[1] *Journ. Anat. and Physiol.* October 1894.

running outwards from the main central portion. The significance of these figures is probably as follows: F. H. Scott[1] has shown that the Nissl's substance is a nucleo-proteid, which amongst reptiles remains throughout life intranuclear, but which in other vertebrates is found outside the nucleus. Taking these facts into consideration, we are led to conclude that the crescent is a specially modified part of the nuclear membrane through which normally the nucleo-proteid is passed out into the body of the nerve-cell. That similar nucleo-proteids do pass out in ordinary epithelial cells has been ascertained in inflammatory conditions of the epidermis,[2] and in gland-cells generally.[3]

On comparing epithelial with nerve cells we find in both a system of fibrils which runs right through the cell; secondly, material secreted by the nucleus and occupying a position between the fibrils, and lastly a system of intracellular lymph channels (Holmgren). During the last year the existence of these channels in the nerve-cells of the spinal, sympathetic, and central nervous systems of the rabbit, cat, and monkey has been confirmed by using erythrosin instead of eosin in conjunction with toluidin-blue. Holmgren holds that these canals serve to carry a free supply of lymph to the nerve-cell, while Mann suggests that they are tubes which carry away from the cells and towards the fields of conjunction ensymes for the elaboration of the lymph, so as to make the latter directly assimilable by the cell processes. Nissl's bodies, then, are zymogen granules secreted by the nucleus, stored up during rest, and discharged during activity.[4]

Golgi's intracellular network in spinal ganglia and the anterior horn cells of the spinal cord may be demonstrated by fixing tissue in $2\frac{1}{2}$ per cent. potassium iodide saturated with iodine, and then taking them through aceton into paraffin. The network seems in the spinal ganglia to form a framework on which Nissl's substance is deposited. The latter is removed by the potassium iodide, while the framework remains.

Other points which the serial sections have brought out are:—

1. The mesencephalic (so-called descending) root of the fifth nerve arises from cells which are quite distinct from the cells of the *Locus cœruleus*. Their axis cylinders have very distinct nodes of Ranvier.

2. The sensory decussation, as shown in the fillet, is only a more pronounced condition of a general arrangement, holding good for the whole length of the cord, the decussating fibres being derived from a small-celled nucleus situated on a level with, and lateral to, the central canal. The afferent fibres to it correspond to Pal's dorsal bundle. The two nuclei are connected by a commissure of very fine medullated nerve-fibres running dorsally to the well-known anterior white commissure.

3. Stilling's sacral and cervical nuclei, Clarke's dorsal column, Blumenau's nucleus, Deiter's nucleus, and the cells of the mesencephalic root of the fifth nerve seem to belong to the same system, which lies dorsolaterally, and is characterised by large cells. The nucleus above referred to under No. 2, the gracile and cuneate nuclei proper, the mesial triangular nucleus of the eighth nerve, and the *Locus cœruleus* form a dorsomesial system containing small cells.

[1] *Trans. Canadian Institute*, 1898–99.

[2] Mann, *Histology of Vaccinia*, L.G.B., 1899.

[3] Trambusti, Galeotti, Huie.

[4] The intracellular lymph channels are well shown in the electrical nerve-cell of Malapterurus. The structure of this cell was displayed at the Liverpool meeting of the British Association by Mann's charts, &c. (1895).

Electrical Changes in Mammalian Nerve.—Report of the Committee, consisting of Professor F. GOTCH (*Chairman*), Professor E. H. STARLING, Dr. J. S. MACDONALD (*Secretary*). (*Drawn up by the Secretary.*)

THE experiments performed with the assistance of grant from the Association have been directed towards the acquisition of information as to the effect upon the demarcation current of mammalian nerve of alterations in resistance, such as are found in mammalian nerve accompanying changes of volume and of blood-pressure in the vessels supplying the nerve. The nature of the changes of resistance is easily determined but the effect of such a change in presumably causing not only an alteration in the magnitude, but also in the distribution of current and differences of potential in the nerve, is not easy to calculate.

Not only this, but it is impossible even to decide the direction of change (addition or subtraction) in the demarcation current which would be produced by any alteration of the internal resistance of the nerve.

Knowledge of an exact character is required for this purpose, defining the limits of the demarcation source and the extent to which the source is short-circuited in the tissues of the nerve itself. It was felt that such knowledge must be based entirely upon experiments upon nerve, and as far as possible upon the particular nerve for which the information was desired.

With this object a large number of experiments have been performed upon excised mammalian nerve. The nerves after removal were placed upon a number of non-polarisable electrodes (four to seven), the potential differences between each pair of electrodes determined, as also the resistances of the whole nerve and the sections into which it was divided by the electrodes. The electrode upon which the cross-section lay was then permanently connected by a wire or through a known resistance to one of the other electrodes, and the differences of potential between each possible pair of electrodes determined again after the formation of this circuit.

An analysis of the data gained by determination of the various resistances divides the facts of experiments into the following groups :—

(*a*) The resistance per centimetre determined from the measurement of resistance of any given length of the nerve varies with that length, being smaller for the greater length.

(*b*) The resistance of the whole nerve directly determined is a smaller value than its resistance calculated from a summation of the resistances of the several sections between pairs of electrodes.

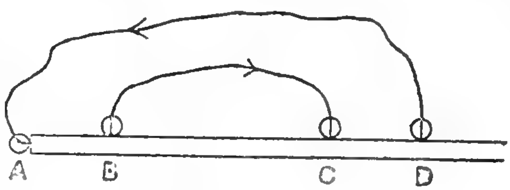
(*c*) The resistance of that section of the nerve bounded by the cross-section gives a smaller value for the resistance per centimetre of the nerve than any other section.

An observation of these facts has led to a routine method for calculating the resistance of any short length of nerve when the resistance required is not that to a current entering and leaving at the extremities of the short length, but the gross longitudinal resistance to a current travelling in paths parallel to the long axis of the nerve. The resistance obtained from the longest available stretch of nerve provided with a cross-

section at either end and calculated into resistance per centimetre is the standard of gross longitudinal resistance, and multiplied by the length of short piece of nerve gives the value required.

The determination of the differences of potential, or, as it is preferred to call them, the available E.M.F.'s between pairs of points on nerve, and calculations based upon these and upon the known resistances, have given interesting information.

(*a*) When the cross-section is connected to a point on the longitudinal surface, the current found in the outer circuit passing from longitudinal surface to cross-section can be found traversing the nerve from cross-section to longitudinal surface, by the new differences of potential acquired by intervening points on longitudinal surface of nerve. A galvanometer circuit between two such intervening points shows a current reverse in direction to that in the outer circuit, and the difference of potential between two such points is exactly that which would be the case if they are considered simply as points upon a circuit, the only source of E.M.F. in which is the P.D. between the extreme points, and with a certain fraction of the total resistance between them; which fraction is that given by the relation of the portion of the gross longitudinal resistance of the nerve between the points to the resistance of the primary external circuit and the resistance of the nerve subtended by its points of application.



If there is a pre-existing difference of potential between the two intervening points (longitudinal current) before the primary external circuit is formed, this difference remains and subtracts from the difference of potential caused by the closure of this circuit. It is concluded from this that the sources giving rise to the two phenomena are separate, and capable of existing simultaneously with an opposition of effects.

Further, by tracing the differences of potentials round the circuit formed by permanently joining the cross-section to a point on the longitudinal surface it is possible to define the limits of the demarcation source.

In consequence of the behaviour of points possessing a difference of potential, the cause of longitudinal currents, an examination has been made of electrotonic currents, and it is found that quite similarly the closure of a circuit placed for the observation of an electrotonic current creates differences of potentials in intervening points of nerve due to a passage in the nerve of a current in the reverse direction, which reverse current may be observed by connecting up the intervening points through a galvanometer; and that in this case also the differences of potential in intervening points can be calculated from a knowledge of that portion of the gross longitudinal resistance which lies between them.

In all these cases the currents observed—demarcation current, longitudinal current, electrotonic current—can be demonstrated in this exact manner to be new creations, the result of the connecting up of the observation circuit. The institution of the external circuit not only provides for the first time a current through this external circuit, but also the traverse of the same current in a return, and therefore reverse, direction through the nerve.

(*b*) Experiments have also been performed with reference to the question of the dependence of the E.M.F. of demarcation source upon the sectional area of the nerve and number of individual fibres contained in it. It has been found that the laying of two nerves side by side with their cross-sections upon the same electrode does not increase the available E.M.F., whilst adding to the current by a diminution of resistance; but that if one of the nerves is drawn along the other and away from this electrode, so that the cross-section of one remains upon the electrode, but that of the other is removed from it, but lies in contact with the longitudinal surface of the first nerve, then there is an increase of the available E.M.F. This summation of the E.M.F.'s, due to either singly, increases with the distance between the two cross-sections up to a certain limiting distance when the maximum summation is reached. It is believed that from the details of such experiments interesting evidence can be obtained of the position and limits of the demarcation source and current within the nerve.

The experiments also provide a considerable amount of evidence as to the dependence of the available E.M.F. between cross-section and longitudinal surface upon the distance of point on longitudinal surface from the cross-section. It is believed that the E.M.F. increases up to a certain point when a maximum is reached, and that this maximal value is obtained until the second cross-section at other end of nerve is approached.

It is also believed that a similar law is true for longitudinal currents, as also for electrotonic currents, namely, that with the proximal electrode upon a fixed point the removal of the distal electrode further and further from this point produces the same kind of variation.

In addition it is reported that in reference to the further error to which it was conceived the variations of blood-pressure in the blood-vessels of a mammalian nerve might give rise—namely, to electromotive phenomena similar to those recorded in case of the carotid and femoral arteries—a number of experiments have been conducted to decide the causation of this phenomenon. It was considered for purposes of further experiment that its causation might be due to (1) changes in the muscular walls of arteries; (2) variations in a conceivable current due to frictional flow through the peripheral vessels.

Experiments carried out upon these two lines have produced some evidence in support of (1), but none in support of (2). In case of the latter supposition the perfusion of saline solution through excised organs under varying pressure was not found to be productive of any current changes other than such as might be explained by changes of resistance &c., which were also measured.

The Physiological Effects of Peptone and its Precursors when introduced into the Circulation. Report of a Committee, consisting of Professor E. A. SCHÄFER, *F.R.S.* (*Chairman*), Professor C. S. SHERRINGTON, *F.R.S.*, Professor R. BOYCE, *and* Professor W. H. THOMPSON (*Secretary*). (*Drawn up by the Secretary.*)

DURING the year, control work arising out of the research was in the first place brought to a completion and will shortly be published. This deals with the influence which the solvent employed in the peptone

experiments—viz., physiological solution of sodium chloride—when injected in small quantities, produces upon the functions of the kidney.

In the next place, attention was directed to the effects which certain constituents of antipeptone—viz., arginin and lysin—exert upon metabolism.

Two methods were adopted for this purpose.

In one form of experiment, a solution of the substance under consideration was injected into the circulation, urine being collected for definite periods before and after the injection. This showed, *inter alia*, that neither of the substances reappeared as such, in any appreciable quantity, in the urine. The full results are not, however, ready for publication.

In the second class of experiment, an animal was brought into nitrogenous equilibrium and the substance administered, either by addition to the diet or by subcutaneous injection.

These latter experiments are of necessity very laborious, and slow in yielding results. They are, moreover, only in their commencement. Nevertheless, very interesting facts promise to arise out of them. For example, a pronounced form of glycosuria seems to be caused by the subcutaneous injection of arginin. The work has, however, not yet been controlled, and it would obviously be premature to go further into the facts.

Hitherto, the necessary arginin and lysin have been generously placed at my disposal by Professor A. Kossel, of Marburg. These substances are, however, very expensive to produce, and it can hardly be hoped that a sufficient supply will in future be available from this source. The experiments are also in themselves more costly than those of former years. For these reasons, as well as on account of the important results which they promise to yield, it is deemed necessary to apply for an increased grant, viz., of 40*l*.

The secretary has been responsible for the carrying out of the work.

Vascular Supply of Secreting Glands.—Report of the Committee, consisting of Professor E. H. STARLING (*Chairman*), Dr. J. L. BUNCH (*Secretary*), *and* Dr. L. E. SHORE, *on the Effect of Chorda Stimulation on the Volume of the Submaxillary Gland. (Drawn up by the Secretary.)*

CHANGES in volume of the submaxillary gland may be brought about both by variations in the flow of blood to the gland and of secretion from the gland. Not so long ago it was believed that a distinct causal relationship existed between vascular supply and secretion; that fluid was secreted from the gland as a result of increased intracapillary pressure, and the discovery by Claude Bernard of the vaso dilator action of the chorda tympani—the chief secretory nerve then known—lent additional weight to this theory. But the theory was disproved by Ludwig, who showed that the dog's submaxillary could be made to secrete by stimulation of the cervical sympathetic nerve, though such stimulation caused vasoconstriction and not vaso-dilatation, and that the pressure in the gland-duct could exceed the pressure even in the carotid artery. Other facts were discovered, such as the paralysis of the secretory fibres of the

chorda by atropine, although the vaso-dilator fibres of the nerve remained unaffected, and the secretion which can be obtained as a result of chorda stimulation unaccompanied by vaso-motor changes after degeneration of the nerve for two or three days.

It cannot, however, be said that the problem of secretion has lost its complexity even now, for we know that secretion may be accompanied by vaso-constriction or by vaso-dilatation; that it may in some cases be paralysed by quinine or atropine, in others not; and that in the same gland stimulation of one nerve may give rise to a secretion having quite different characteristics from that brought about by excitation of another nerve.

In order to investigate the action of the chorda on the volume of the submaxillary gland I have employed a plethysmograph of very simple construction, devised by Professor Schäfer, which consists of a gutta-percha box with one side of glass, thus enabling the gland to be kept directly under observation, and any flushing or pallor of the superficial vessels to be accurately noted. The vessels and gland-duct enter the box on one side through an opening sufficiently large to prevent any pressure being exerted upon them, and the rest of the aperture is closed by cotton-wool and thick vaseline. Only a very small portion of the duct where it emerges from the hilum is contained within the plethysmograph, and the box is so supported by means of a clamp that the portion of duct outside it is quite loose, and no contraction of the longitudinal fibres of the duct can pull upon or otherwise affect the volume of the contents of the box. The box is connected with a tambour or piston-recorder, which writes on a smoked paper, by an indiarubber tube attached to a glass tube which passes through one side of the box, the whole apparatus being filled with air. A lateral tube leads from this connecting tube, and is closed with a spring clip, so that the pressure within this air-tight system can be raised or lowered at any moment. The tracings obtained in many cases show most distinctly both heart-beats and respiratory curves.

The chorda was exposed after division of the digastric muscle, ligatured, and cut, and the peripheral end stimulated by means of Ludwig's electrodes, which were left *in situ*. In some cases, the chordo-lingual nerve was divided centrally and the peripheral end stimulated; any injury to the more slender chorda through manipulation was thus avoided. The nerve was excited by currents of different strengths, and with varying rates of repetition of this stimulus, and the anæsthetic was varied in different experiments. With a moderately weak stimulus excitation of the chorda produced considerable diminution in volume of the gland and a fall of the lever of the piston-recorder. The fall was preceded by a short latent period when the gland was secreting freely, and rapidly reached its maximum when the stimulation was a short one. When the current was shut off the lever still remained at its lowest point for a short time, which varied in duration according to the length of passage of the current. The gland then very gradually again increased in volume, and the lever rose until it once more reached the base-line. This recovery in volume was succeeded by dilatation of the gland and further rise of the lever to a point well above the base-line, after which it again gradually fell. The extent of this dilatation varied according to the previous diminution in volume of the gland, being greater and more prolonged when the diminution of gland volume had been well marked, but the after-rise of the lever did not equal in extent or duration its previous fall. This diminution in

gland volume was accompanied by a free flow of secretion from the duct, the amount of which was measured, and by marked dilatation of the vessels of the gland.

With a stronger stimulus the latent period was shorter, the flow of saliva greater, and the diminution in volume of the gland more abrupt and of greater range. The recovery of volume was also slower, and the after dilatation more marked. When the excitation was a long one, more especially with a strong current, the recovery of the gland was considerably prolonged, and the rise of the lever a very gradual one. As long as both gland and nerve remained in good condition successive stimulations of the chorda repeated as soon as the gland had returned to its original volume still continued to produce the same effect, with but little difference in diminution of volume in response to stimuli of the same strength and duration. If, however, the nerve was stimulated a second time, either immediately after the first excitation or while the lever was still rising, the resulting diminution in volume of the gland was less than that preceding it, this difference being greater the more quickly the second excitation succeeded the first. When the secretion produced by chorda stimulation was scanty and viscid, in spite of the accompanying active vaso-dilatation, stimulation of the nerve caused either a very small fall of the lever or a preliminary fall succeeded by a rise. In some cases, more especially when there was some obstruction to the free escape of blood through the veins, and also scanty secretion, chorda excitation gave rise to increase of volume of the gland, owing to the increased flow of blood to the gland more than compensating for the small amount of secretion leaving it. After the administration of small doses of atropine intravenously, sufficient to paralyse the secretory fibres of the chorda (8–12 mg. for a dog of 7 kilos.), stimulation of the peripheral end of the divided chorda caused no flow of secretion from the duct, but an active dilatation of the gland and a rise of the piston-recorder lever to an extent about equal to the previous fall of the same lever brought about by a stimulus of the same strength and duration before any atropine had been administered.

The absolute increase or diminution in the volume of the gland under various conditions was estimated by calibration of the piston-recorder, the rise or fall of the lever for fractional parts of a cubic centimetre being marked out on a scale. The volume of the gland in cubic centimetres was determined from the difference between its weight in air and in water, and the amount of secretion produced by nerve stimulation or otherwise was also determined by connecting the cannula in the duct with a glass tube graduated in fractional parts of a c.c. In order to determine the total diminution in volume of the gland, due to chorda stimulation, the diminution in volume of the gland was first determined in an etherised dog before the administration of atropine, and then the increase in volume of the same gland after the administration of a dose of atropine sufficient to paralyse the secretory fibres of the chorda. By adding the two amounts together the total loss of gland contents due to chorda stimulation was obtained. On comparing this with the amount of secretion poured out in the same time we found that at least $\frac{9}{10}$ of the secretion was derived from the extra-vascular portions of the gland. Since there is no diminution in the lymph flow from the gland, but rather a slight increase during the period of stimulation (Bainbridge), we must conclude that the effect of the secretory nerves is simply and solely upon the

secretory cells, the increased exudation from the blood-vessels which must in the last instance supply the fluid for the secretion being a secondary phenomenon determined entirely by the metabolic changes of the cells, and lagging behind these to a very considerable extent.

Age of Stone Circles.—Report of the Committee, consisting of Dr. J. G. GARSON (*Chairman*), Mr. H. BALFOUR (*Secretary*), Sir JOHN EVANS, Mr. C. H. READ, Professor R. MELDOLA, Mr. A. J. EVANS, Dr. R. MUNRO, *and* Professor W. BOYD DAWKINS.

THE Committee have to report that various possible sites have been discussed and the necessary inquiries have been made during the past year, and negotiations are now in progress which it is hoped will enable the Committee to begin the actual work of section cutting during the ensuing year at Arbor Low Stone Circle in Derbyshire, permission for which has been kindly granted by his Grace the Duke of Rutland.

The Committee request to be reappointed with the disposal of the unexpended balance of the grant, with which it is proposed to make one or two trial sections of the ditch and rampart of the circle.

Mental and Physical Deviations from the Normal among Children in Public Elementary and other Schools.—Report of the Committee, consisting of Mr. E. W. BRABROOK (*Chairman*), Dr. FRANCIS WARNER (*Secretary*), Mr. E. WHITE WALLIS, Dr. J. G. GARSON, *and* Dr. RIVERS. (*Drawn up by the Secretary.*)

THE Committee, acting in conjunction with the Childhood Society for the Scientific Study of the Mental and Physical Conditions of Children, have, through the assistance of that society, been able to use the cards recording the 'cases with any abnormal nerve-sign,' as seen 1892–94; that is, 2,851 boys, 2,003 girls, as found among 26,287 boys, 23,713 girls examined.

As a new method of research these cases are arranged in primary groups containing the children who presented nerve-signs in (1) the face only ; (2) the hand only ; (3) eye-movements defective only ; and (4) a group showing nerve-signs in other parts of the body only.

In making a rapid examination and report on children examined in schools, it may be convenient to classify nerve-cases in four groups as presenting signs in (1) face (defect of expression, overaction of the frontal muscles, knitting the eyebrows, muscular relaxation about the lower eyelid) ; (2) in balance of the hand or finger twitches ; (3) irregular movements of the eyes ; (4) in general balance of the head and other parts

of the body. Twenty-one nerve-signs have been observed and defined;[1] the cases presenting these signs are here grouped in classes under the headings named according to the parts of the body in which they are seen.

The tables given in the appendix may now be described.

The total number of children with any class of nerve-signs is obtainable by adding the eight primary groups presenting that class, thus: Among the children 7 years and under, adding the eight lines enumerating signs in the face gives a total of 343 boys, 179 girls. Again, addition of the three lines enumerating signs in face and eye-movements gives a total of 21 boys, 20 girls, with the two classes of nerve-signs.

The numbers in each primary group of nerve-cases are given in the last column of the table, and are distributed again as primary groups according to the main classes of defect observed associated with the nerve-signs. Thus:

Column headed B gives cases with nerve-signs only.
AB=Nerve-signs associated with development defect only.
BC=Nerve-signs associated with delicacy only; children pale or thin.
BD=Nerve-signs with mental dulness only.
ABC=Nerve-cases with developmental defect and delicate only, *i.e.* not dull or backward.

From these tables the compound groups can be formed by addition of the primary groups composing them, and from these the correlations of the classes of nerve-signs with the main classes of defect can be obtained after the method explained in Dr. Warner's paper, published in the 'Journal of the Royal Statistical Society,' March 1896.

Among the nerve-cases here reported on, the relative frequency of nerve-signs in the face, the hand, and in eye-movements is shown to be as follows:—

Age-groups	Total No. of Cases		Face Total No. of Cases		Eye-movements Total No. of Cases		Hand Total No. of Cases	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
7 years and under . .	742	489	343	179	94	74	300	209
8–10 years . . .	1,229	878	473	250	153	127	690	503
11 years and over . .	880	636	317	141	104	58	530	426
At all ages . . .	2,851	2,003	1,133	570	351	259	1,520	1,138

Other researches were made, but when they did not appear to supply useful information the results were not included in the tables. It was thought that there might be a definite association between irregular movements of the eyes and twitchings of the fingers; the facts given below do not support the premiss. Again, the association between irregular eye-movements and overaction of the frontal muscles (frowning) is not very marked, though more frequent than in the last case.

[1] See *Report on the Scientific Study of the Mental and Physical Conditions of Children, based on the examination of* 100,000 *children*, p. 76. Published at the Parkes Museum.

Primary Groups	Age Groups					
	7 and under		8–10		11 and over	
	Boys	Girls	Boys	Girls	Boys	Girls
Eye-movements and finger twitches only	—	—	—	—	—	—
Eye-movements and finger twitches and other nerve-signs . . .	2	1	7	3	2	—
Eye-movements and frontals over-acting only	7	2	12	2	3	—
Eye-movements and frontals and other nerve-signs	5	2	16	2	9	2

This Committee, first appointed in 1892, have reported each year, and information thus supplied concerning the mental and physical conditions of childhood has afforded evidence in a wide field of research. Among other problems advanced it has been shown that, with certain constitutional conditions of congenital deficiency and acquired defects as found among boys and girls respectively, the status varies in the age-groups. It appears highly probable that the heavy mortality under five years of age, which falls principally on the boys, is largely due to developmental defects, while children with such congenital defect who survive add largely to the proportion of the dull and delicate pupils in schools, and to the number of neurotic persons who often fail in health at adult age.

The main classes of defect among children are more frequent with boys, while the girls with defective constitution tend in larger proportion than the boys to ill-health and brain disorderliness.

To summarise problems previously demonstrated, development-defect cases are very frequently delicate and dull. Children with (motor) brain disorderliness are often dull; so are the children who are naturally delicate. Dull pupils often present defect in development as well as delicacy and (motor) brain disorderliness needing special care and training.

Departures from the normal are more frequent among males; but the females with developmental defect or brain disorderliness are more apt to receive harm and to receive less good from their environment than males. This indicates the care required, and is illustrated by the more hopeless condition of female lunatics and criminals.

It has been shown that good effects follow the employment of physical training at school in diminishing the number of children with signs of brain disorderliness and the proportion of dull pupils.

Children in poor-law and industrial schools are below the average in bodily development and mental ability. It appears that home life and day school training are more advantageous than institution training.

The investigations that have been carried out and study of the distribution of cases of developmental defect in various localities have suggested that sanitation and the practical application of hygienic principles to school life may lessen the frequency of developmental defects and the proportion of mental and physical weakness and mortality coattendant.

In conclusion, it has been shown by many examples that detailed examination and report on the children in selected schools have proven many points of social and scientific value.

The Committee desire to be reappointed to continue research in conjunction with the Childhood Society, and ask a grant of 5*l*. in aid of this work.

APPENDIX.

Children aged 7 years and under, showing numbers of Boys and Girls with each Group of Nerve-signs as indicated, arranged in Primary Groups. These are also distributed according to the Main Classes of Defect present in Primary Groups.

Children aged 7 Years and under

Primary Groups: Presenting Nerve-signs in the parts mentioned only	B		AB		BC		BD		ABC		ABD		BCD		ABCD		Total Cases	
	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B		B.	G.
Face only	68	21	28	17	11	8	57	19	12	8	19	17	13	5	7	11	215	106
,, and Eye-movements only	2	6	1	4	3	1	4	2	2	—	3	2	2	—	1	1	18	16
,, and Hand only	17	4	8	—	5	2	8	5	2	2	3	3	2	—	2	1	47	17
,, and other Nerve-signs	10	2	6	2	—	3	16	5	2	3	7	7	4	2	4	5	49	29
,, Eyes and Hand	—	—	—	—	—	—	2	1	—	1	—	—	—	—	—	—	2	2
,, ,, and other Nerve-signs	—	1	—	—	2	—	3	1	—	—	2	—	1	—	—	2	8	4
,, Hand and other Nerve-signs	1	1	—	2	—	—	—	—	1	—	1	—	—	—	—	—	3	3
,, Eyes, Hand & other Nerve-signs	—	—	—	—	—	—	—	1	—	—	—	1	—	—	1	—	1	2
Eye-movements only	11	8	13	1	6	1	3	3	1	4	5	4	5	2	2	2	46	25
Eye and Hand	4	5	2	1	—	—	2	1	—	—	2	—	—	1	—	—	10	8
,, and other Nerve-signs	2	1	—	—	—	—	3	5	—	1	1	2	—	1	—	2	6	12
,, Hand and other Nerve-signs	1	—	—	—	—	1	1	3	—	1	1	—	—	—	—	—	3	5
Hand only	89	45	39	21	10	10	46	26	7	5	11	14	4	4	7	8	213	133
,, and other Nerve-signs	7	19	2	5	—	2	5	7	1	1	3	2	—	2	3	1	21	39
Other Nerve-signs	20	15	14	9	2	7	25	27	6	9	18	8	9	4	6	9	100	88
	232	128	113	62	39	35	175	106	34	35	76	60	40	21	33	42	742	489
																	1,231	

Children aged 8 to 10 Years

Primary Groups: Presenting Nerve-signs in the parts mentioned only	B		AB		BC		BD		ABC		ABD		BCD		ABCD		Total Cases	
	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B		B.	G.
Face only	97	38	42	8	10	10	67	33	5	9	33	16	10	10	8	10	272	134
,, and Eye-movements only	9	1	4	2	1	1	6	7	—	—	4	2	—	—	1	1	25	14
,, and Hand only	50	13	10	2	3	2	17	9	3	3	9	4	1	2	3	—	96	35
,, and other Nerve-signs	10	13	4	5	3	2	17	10	1	—	13	8	2	2	2	—	52	40
,, Eyes and Hand	3	4	3	—	2	1	4	—	—	—	1	—	—	—	—	—	13	5

Face, Eyes, and other Nerve-signs	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	1	2	—	1	—	—	4	10
„ Hand and other Nerve-signs	5	6	1	1	1	1	3	1	—	1	—	—	—	—	—	—	10	10
„ Eyes, Hand & other Nerve-signs	—	1	—	—	—	—	—	1	—	—	—	—	1	—	—	—	1	2
Eye-movements only	12	8	15	13	3	3	9	11	3	2	10	7	4	1	3	3	59	48
Eye and Hand	18	13	3	4	—	2	13	6	1	—	—	2	—	4	1	2	36	33
„ and other Nerve-signs	3	3	—	—	—	1	2	5	—	—	3	1	—	—	—	1	8	11
„ Hand and other Nerve-signs	5	2	—	—	—	—	1	1	—	—	1	1	—	—	—	—	7	4
Hand only	215	169	55	31	16	11	121	76	9	5	50	27	9	10	9	5	484	334
„ and other Nerve-signs	17	35	7	8	3	3	13	21	1	2	2	8	—	1	—	2	43	80
Other Nerve-signs	22	34	25	21	4	5	27	24	3	7	22	17	8	6	8	4	119	118
	467	342	169	95	46	42	302	210	26	29	149	95	35	37	35	28	1,229	878
																	2,107	

Children aged 11 Years and over.

Face only	64	24	27	5	6	4	55	26	2	6	20	6	2	5	4	4	180	80
„ and Eye-movements only	2	1	—	—	1	—	5	—	—	—	1	—	—	—	—	—	9	1
„ and Hand only	30	9	8	4	3	1	19	6	—	—	3	1	3	1	3	—	69	22
„ and other Nerve-signs	14	6	2	1	3	1	9	5	—	—	2	5	1	1	—	2	31	21
„ Eyes and Hand	3	—	—	1	—	—	1	—	—	—	—	2	—	—	—	—	4	3
„ „ and other Nerve-signs	—	1	1	—	—	—	2	2	—	—	2	1	—	—	1	—	6	4
„ Hand and other Nerve-signs	4	3	2	—	1	1	3	3	—	—	4	—	—	—	2	—	16	7
„ Eyes, Hand & other Nerve-signs	1	—	—	—	—	—	1	—	—	—	—	3	—	—	—	—	2	3
Eye-movements only	15	9	12	—	1	1	6	3	1	—	3	6	—	—	—	—	38	19
Eye and Hand	13	8	5	2	—	1	10	7	—	—	1	2	—	—	1	—	30	20
„ and other Nerve-signs	2	4	1	—	2	—	3	—	—	—	—	3	1	—	1	1	10	8
„ Hand and other Nerve-signs	3	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	5	—
Hand only	169	166	58	22	10	17	85	76	5	4	34	21	4	3	—	2	365	311
„ and other Nerve-signs	16	29	4	4	1	2	10	20	—	—	6	4	2	1	—	—	39	60
Other Nerve-signs	22	25	13	9	3	3	16	22	1	3	17	15	2	—	2	—	76	77
	358	285	133	48	31	31	226	170	9	13	94	69	15	11	14	9	880	636
																	1,516	

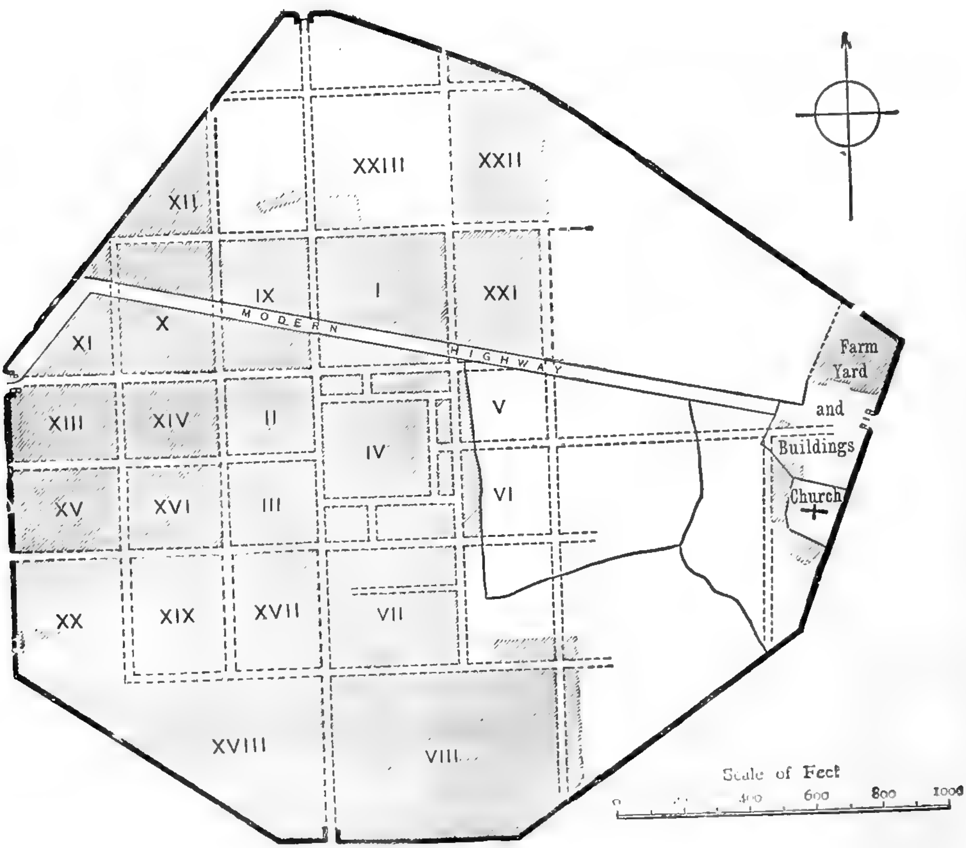
Note.—Since this report was drawn up an important mathematical paper 'On Association of Attributes in Statistics, with Illustrations from the Material of the Childhood Society &c.,' by Mr. G. Udny Yule, has been published in the 'Philosophical Transactions of the Royal Society.' The suggestions there made as to statistical methods of presenting correlations are likely to prove most useful in future research.

Charts have been prepared from these Reports by Mr. C. S. Loch and exhibited at the Paris Congress by the Charity Organisation Society.

Silchester Excavation.—Report of the Committee, consisting of Mr. ARTHUR J. EVANS (*Chairman*), Mr. J. L. MYRES (*Secretary*), *and* Mr. E. W. BRABROOK, *appointed to co-operate with the Silchester Excavation Fund Committee in their Excavations.*

THE Committee has to report that the excavations at Silchester in 1899 were begun on May 5, and continued, with the usual break durin the harvest, until November 16.

The examination of the south-west quarter of the town having been



completed in 1898, it was resolved to continue the excavation of the northern half of the site. To suit the convenience of the tenant, the operations of 1899 were restricted to the *insula* (XXI) east of *insula* I

(which was excavated in 1890–1), and to another *insula* (XXII) north of XXI, extending nearly as far as the town wall. The total area examined was about 5½ acres. The block plan shows the parts already excavated in shaded tint.

Insula XXI appears to have been enclosed by walls on all four sides. In addition to two houses occupying the northern corners, it had on its eastern side a large house of the courtyard type, with another small house to the south of it. At the south-east angle of the *insula* was situated an oblong chamber with an apsidal end, perhaps the meeting room of some trade guild. Other traces of buildings were found along the south side. The south-west angle unfortunately underlies the modern roadway through the city, and could only partly be examined. The western side contained two small square structures. With regard to the houses, that at the north-west corner was discovered in 1864 by the Rev. J. G. Joyce, who communicated an account of it to *Archæologia.* It was, however, only partly excavated by him, and additional chambers have now been found on the south and east. The north-east house is one of the corridor type that has become a courtyard house by later additions. In one of the added rooms was a hypocaust of peculiar plan. The large house on the east side is of interest from the several changes it has undergone, as well as on account of the traces of a series of mosaic pavements of simple character. The small house to the south is remarkable for the number of pits and wells found beneath it. From these were extracted several whole vases, some of an early type and excellent design.

Insula XXII, though equal in size to the other, contained a large amount of open ground in the centre and north-west. As there were no signs of a street on its eastern side, the portion excavated may form part of a larger *insula.* Near the south-west angle was a good-sized house of the corridor type, with a large chamber at one end terminating in an apse, which had a hypocaust beneath it. A square chamber of some size which had been added on one side has foundations of huge blocks of ironstone, and the same material has been used in what appears to have been a reconstruction of the western part of the house. Besides this house, portions of three others were found. Two of these were of very little interest. The remains of the third include a square block subdivided into two chambers of unequal size, with an apse attached to one side All these had been warmed by hypocausts.

As usual, a number of wells were met with, lined with wooden framing towards the bottom. No architectural remains of any importance were met with, save a piece of coping, part of a fluted Purbeck marble pilaster, and a fragment of a white marble slab. The finds in bronze, iron, glass, and bone were as numerous as usual, but do not call for special notice. From the pits examined an exceptionally large number of entire vessels of pottery were recovered, the total being about eighty. They include several pseudo-Samian vases of unusual quality, an inscribed drinking cup of Castor ware, some large vessels of the coarse ware which is so seldom found entire, &c., &c. The coins found were not very numerous.

A detailed account of all the discoveries was laid before the Society of Antiquaries on May 3, 1900, and will be published in *Archæologia*, LVII. A special exhibition of the antiquities, &c., found, was held, as in former years, at Burlington House.

The statement of accounts for the year 1899 shows a total expenditure of 515*l.* 0*s.* 7*d.*

It is proposed, during the current year, to excavate the large area north of *insulæ* I and IX, which extends up to the north gate. The Committee therefore asks to be reappointed, with a further grant.

Ethnological Survey of Canada.—Report of the Committee, consisting of Professor D. P. PENHALLOW (*Chairman*), Dr. GEORGE M. DAWSON (*Secretary*), Mr. E. W. BRABROOK, Professor A. C. HADDON, Mr. E. S. HARTLAND, Sir J. G. BOURINOT, Abbé CUOQ, Mr. B. SULTE, Abbé TANGUAY, Mr. C. HILL-TOUT, Mr. DAVID BOYLE, Rev. Dr. SCADDING, Rev. Dr. J. MACLEAN, Dr. MERÉE BEAUCHEMIN, Mr. C. N. BELL, Professor E. B. TYLOR, Hon. G. W. ROSS, Professor J. MAVOR, Mr. A. F. HUNTER, *and* Dr. W. F. GANONG.

THE work of the past year has furnished conspicuous evidence of the great importance of securing ethnological data with as little delay as possible. While this is eminently true with respect to the white population, which is experiencing new and marked changes almost every year, in consequence of the introduction of foreign elements, often in large numbers, it is more particularly true with respect to the native Indian population. In many localities the original blood has become so diluted by intermarriage with whites that it is often a matter of great difficulty to find an Indian of pure blood. Proximity to settlements of white people has resulted in a more or less profound impress upon the social life and tribal customs, which are fast becoming obsolete and forgotten. The old chiefs who have served as the repertories of traditionary knowledge are rapidly passing away, and with their death there disappears the last possibility of securing reliable data of the greatest value. Conspicuous instances of this kind have been brought to notice during the past year, especially in the case of the British Columbia Indians, whose ethnology is of the greatest interest and importance in consequence of their possible connection with the people of Eastern Asia. At present the great difficulty of securing competent and willing investigators is one of the most serious obstacles to be contended with, and it is believed that the often considerable expense involved in the prosecution of such work is largely accountable for this condition of affairs.

It is gratifying to note that the Department of Education for Ontario has lately taken a very practical and active interest in ethnological studies in that province, and that it provides for the publication of the results of research in its annual reports. During the past year Mr. A. F. Hunter, of Barrie—a member of this committee—has thus published the results of important studies relating to the archæology of the township of Tay. A *résumé* of this work shows that much light has been thrown upon the extent, characteristics, and condition of the Indian population in prehistoric times. Evidence has latterly been accumulating to indicate the presence at one time of numerous aboriginal settlements in localities which were

very sparsely inhabited when first visited by the white explorers. One of the most fruitful fields in Ontario for the archæologist is afforded by the sites of the numerous Indian villages which abound in the northern portions of Simcoe County, more especially in the townships of Tiny and Tay. A very interesting report on the subject was issued last year by Mr. Andrew F. Hunter, M.A., relating to the Huron Indian relics found in the *former* township, which has just been supplemented by a similar publication in regard to the discoveries in the adjoining municipality of Tay, both being issued as appendices to the Educational Report. A special interest attaches to the investigations made in Tiny, as it includes the spot where Champlain and the early missionaries landed on their arrival in the Huron country, the researches of Mr. Hunter being carried on with a view to the identification of those villages described by these pioneers of civilisation and Christianity. In the territory identified as occupied by the Bear nation, belonging to the Huron confederacy, which embraces Tiny and a portion of Tay township, there were no fewer than forty-nine villages, and twenty-four bone-pits or aboriginal burying-places, have been unearthed. The villages, however, were not all occupied at the same time. Thirty-nine of the number bear evidences that the inhabitants had had some contact with Europeans. A detailed description is given of the various village sites and bone-pits, and the more interesting and valuable of the relics discovered, with numerous illustrations. A site to which particular importance attaches is the ruins of the second fortified Jesuit mission of St. Marie, on Christian Island, with the remains of an extensive Huron village surrounding it. The population is estimated to have been from 6,000 to 8,000 in the winter of 1649–50, when it was decimated by famine and disease.

'Considerable difference of opinion has prevailed as to the spot where the early missionaries Brebeuf and Lallemant were tortured and burned by the Iroquois during the war which almost exterminated the Hurons, and those interested will find many facts bearing upon the controversy in the report dealing with the township of Tay. Mr. Hunter's own view, after a painstaking survey of all the evidence obtainable, is that the site of St. Louis II., where the missionaries were captured when the village was burned, is on the farm of John McDermitt, lot 15, concession IV., where extensive ash-beds have been found mixed with relics. The identity of the village appears to be established by its size, as indicated by the ground, and its location as described by the old writers. Mr. Hunter is inclined to regard the site on the farm of Charles E. Newton, lot 11, concession VI., as that of St. Ignace II., the village to which the captured priests were taken, and where their martyrdom, so powerfully described by Parkman, took place. It has been known locally as the "Jesuits' Field" for many years, and there are the usual traditions of buried treasure which gain currency wherever relics of the past are brought to light. Much interesting information with regard to less notable sites and the frequent discoveries of Indian remains throughout the township are also embodied in this work.'

In Appendix I. Mr. B. Sulte continues his study of the early French settlers in Canada, covering the period 1632–66. He traces the origin of these immigrants from different parts of France, and it thus becomes possible to establish with great accuracy the relative importance of the various stocks from which the present large French population of Canada is derived. These studies will form an important basis for more

detailed investigations respecting the effect of environment upon succeeding generations.

In Appendix II. Mr. Hill-Tout follows up his very careful study of the N'tlaka'pamuQ, appended to last year's report, with a similar close investigation of another and markedly different division of the Salish stock in British Columbia, the Sk·gō'mic. These people previously inhabited Howe Sound and Burrard Inlet in large numbers, but they are now much reduced, and appear to be rapidly passing away. Over ninety villages at one time inhabited are enumerated. Much attention has been given to the language, which had not heretofore been seriously investigated, and which shows numerous grammatical and other peculiarities. Mr. Hill-Tout's work, in fact, constitutes a very important local contribution to the ethnology of the native races of the west coast.

This report is accompanied by nineteen photographs of Indians, taken by Mr. Hill-Tout, partly of the Sk·gō'mic and partly of neighbouring tribes, in which he is now further pursuing his investigations.

The ancient settlement of Huron Indians at Lorette, near Quebec, has always been an object of great interest to the ethnologist, although prolonged and intimate contact with the whites of the neighbourhood has resulted in marked alterations of a physical and social character. These alterations have progressed so far as to make trustworthy studies an exceptionally difficult matter, but the Committee felt that no opportunity to secure such data as might yet be available should be lost, and in Appendix III. Mr. L. Gérin presents the results of a very careful investigation into the actual social condition of these Indians. He brings this into comparison with their original condition, tracing out the influences which have produced great changes among them during their prolonged residence in the province of Quebec, subsequent to the abandonment of their old home. The condition of this community of Hurons offers a marked contrast to that of the originally similar Iroquois community near Montreal, their evolution in modern times having been almost in opposite directions; a circumstance explained by their environment in the two cases. The report is accompanied by photographs showing the present conditions of village life, which will be kept on file for future reference.

APPENDIX I.

Early French Settlers in Canada. *By* B. Sulte.

Following my statement of last year, I beg to submit, first, the result of my observations respecting the number of actual settlers in 1632–66.

In 1632 there were twenty-nine men [1] in the colony, who were either married or who married soon after, and became heads of families. These are the roots of the Canadian tree. A few Frenchmen engaged in the fur trade formed a distinct group outside of the scope of this paper.

In 1640 the 'habitants' numbered 375,[1] distributed as follows:

Married men, 64; married women (three born in Canada), 64; widower, 1; widows, 4; unmarried men, 35; boys (30 born in Canada), 58; girls (24 born in Canada), 48; nuns, 6; Jesuits, 29; other Frenchmen, 66; total, 375.

[1] I have published a biographical sketch of each of them.

According to my calculations, the 'habitants' did not exceed 600 in 1650, besides 40 Jesuits, 40 Jesuits' servants, and 20 other Frenchmen.

The population in 1653 appears to have been distributed in three groups: Quebec, 400; Three Rivers, 175; Montreal, 100; total, 675.

We must add the usual contingent of French traders, which was very small at that time on account of the war of the Iroquois.

It is mentioned in letters dated from Canada, 1661–63, that the entire population (inhabitants, Jesuits, and others) did not exceed 2,500. This embraces the large immigrations of 1662, 1663, which mark a new departure in the whole affairs of Canada.

The reader is referred to the statement in the last Report, covering the period of 1608–1645, with regard to the origin of the 122 men who first settled in the colony. I will now show the origin of 475 more during 1646–1666. These are men who came from France, were already married or married in Canada, and founded families in the colony:—

North-west of France.—Bretagne, 20; Maine, 22; Normandie, 136; Picardie, 10; Ile-de-France, 25; Touraine, 8; Anjou, 18; total, 239.

South-west of France.—Poitou, 60; Rochelle, 138; Bordeaux, 14; total, 212.

East of France.—Champagne, 6; Nivernais, 2; Berry, 3; Dauphiné, 4; Auvergne, 5; Lyonnais, 4; total, 24.

During the same period, 1646–1666, I find 100 marriages without any mention of the origin of the contracting parties; but we may safely infer, from the synopsis just given, that they must be added to the 475 whose origins are known, and distributed according to the relative proportions of that statistic.

Therefore from 1608 to 1666 we have examined 697 men who came from France with their wives, or marrying once settled in the colony.

Until about 1645 the greatest number of them came from the north of river Loire; after that the south-western provinces gradually balanced the emigration from the north—

1646–1666. North of Loire, 231; south of Loire, 220.

Immigrants from Touraine, Poitou, Rochelle, Aunis, Saintonge, Angoumois, Bordeaux, found their way to Canada after 1650, so that the Normandy influence was absolute until about 1660, when Poitou and Rochelle came in for a large share.

The first official census was taken in 1666, and considered imperfect at that time. It gives 3,215 souls for all the New France.

The census (nominal) of 1667 says 3,918 souls. These last figures represent the 697 heads of families above mentioned. The following statement is a *résumé* of that valuable document:—

Families, 668; males, 2,406; females, 1,512; married (625), 1,250; widowers, 20; widows, 26; boys, 1,762; girls, 860.

Ages of the People.

Years	No.	Years	No.	Years	No.	Years	No.
0–1	223	5– 6	122	11–15	241	51–60	156
1–2	186	6– 7	100	16–20	250	61–70	78
2–3	154	7– 8	104	21–30	925	71–80	9
3–4	143	8– 9	84	31–40	582	81–90	9
4–5	148	9–10	103	41–50	281	Not given	20

Ages in Relation to Conjugal Condition.

Years	No.	Years	No.	Years	No.	Years	No.
0–10	0	21–30	403	51–60	96	81–90	4
11–15	2	31–40	409	61–70	49	91–100	
16–20	66	41–50	215	71–80	6		

The number of arpents under cultivation was 11,448, with cattle 3,107, and sheep 85. No horses yet in the colony. All the sheep were run on at River St. Charles, near Quebec.

The land under cultivation shows an average of seventeen arpents per family. The census of 1681 has the same small proportion.

APPENDIX II.

Notes on the Sk·qō'mic of British Columbia, a Branch of the great Salish Stock of North America. By C. HILL-TOUT.

The following notes on the Sk·qō'mic, a division of the Salish stock of British Columbia, are a summary of the writer's studies of this tribe. While he has sought to make them as comprehensive and complete as possible, he is fully conscious that they are far from being exhaustive. There are, indeed, insuperable difficulties in the way of making really exhaustive reports on any of our tribes at the present time. There are, in the first place, many invincible prejudices to be overcome. Then there is the difficulty of communication, and when these have been partially overcome there yet remains the difficulty of finding natives who possess the knowledge you are seeking. Not every Indian is an *Iagoo*, a story-teller; and only the older men or women remember the old practices, customs, manners, and beliefs of the tribe, and even these have forgotten much that is important to know. These and other difficulties stand in the way of complete and exhaustive investigation; and I cannot better illustrate the need of pushing on our work among these interesting peoples without further delay than by stating that since my last report was sent in my principal informant among the N'tlaka'pamuQ, Chief Mischelle, from whom I secured so much valuable information a year or so ago, has passed away, and can render us no further aid. In a few years, all those who lived under the old conditions in præ-missionary days, and who now alone possess the knowledge we desire to gather, will have passed away, and our chances of obtaining any further reliable information of the past will have gone with them.

In my work among the Sk·qō'mic I have been more than usually fortunate, and have been able to bring together much interesting matter not previously known or recorded.

Ethnography.

The Sk·qō'mic constitute a distinct division of the Salish of British Columbia and both in language and customs differ considerably from the coast tribes on the one hand, and the interior tribes on the other. The structural differences of their speech are so great as to shut them off from free intercourse with the contiguous Salish tribes. The tribe to-day numbers less than two hundred souls, I believe. Formerly they were a

strong and populous tribe, numbering, when white men first came into contact with them, many thousands. Some of their larger *ō'kwumūq*, or villages, contained as many as seven hundred people, and that less than fifty years ago. We gather this from the early white settlers themselves.

The original home and territory of the Sk·qō'mic seems to have been on the banks of the river which gives them their tribal name, and along the shores of Howe Sound, into which the Skuamish runs. Their settlements on the river extended for upwards of thirty miles along the banks. Their northern neighbours were the Lillooets or StlatlumH tribe and the Tcilkōtin division of the Déné stock. Their southern neighbours were the Lower Fraser tribes. According to one of my informants the Indian villages that used to exist on English Bay, Burrard Inlet, and False Creek were not originally true Sk·qō'mic. They were said to be allied by speech and blood to the Lower Fraser tribes. How far this is correct seems impossible now to say. Sk·qō'mic is everywhere spoken throughout this territory, and has been as far back as our knowledge of it goes; and the Sk·qō'mic villages, according to my informants, extend to and include *Mā'li*, at the mouth of the Fraser, which place Dr. Boas was informed by the River Indians belonged to them, and which he has accordingly included in their territory. It was probably the dividing line, and, like Spuzzum, farther up the river, was composed partly of the one division and partly of the other.

Our first knowledge of the Sk·qō'mic dates back to rather less than a century ago. The first white man to sail into English Bay and Howe Sound and come into contact with them was Captain Vancouver. He recorded briefly his impressions of them in the diary of his voyage to this coast, a short extract from which may be of interest in this first formal account of the tribe. He writes thus :—

Friday, June 15, 1792.[1]

'But for this circumstance we might too hastily have concluded that this part of the Gulf was uninhabited. In the morning we were visited by nearly forty of the natives, on whose approach from the very material alteration that had now taken place in the face of the country we expected to find some difference in their general character. This conjecture was, however, premature, as they varied in no respect whatever, but in possessing a more ardent desire for commercial transactions, into the spirit of which they entered with infinitely more avidity than any of our former acquaintances, not only bartering amongst themselves the different valuables they had obtained from us, but when that trade became slack in exchanging those articles again with our people, in which traffic they always took care to gain some advantage, and would frequently exult on this occasion. Some fish, their garments, spears, bows and arrows, to which these people wisely added their copper garments, comprised their general stock-in-trade. Iron in all forms they judiciously preferred to any other article we had to offer.'

They have not altered much in these points of their character since Vancouver's visit, and many of them have to-day, I am told, snug little sums judiciously invested by their good friend and spiritual director, the late Bishop Durieu, in safe paying concerns. It is only fair to say, however, that they deserve to be prosperous. They are probably the most

[1] Vol. i. p. 305.

industrious and orderly band of Indians in the whole province, and reflect great credit upon the Roman Mission established in their midst.

I obtained the following list of old village sites, not 10 per cent. of which are now inhabited. The list is not perfectly complete. There were a few more villages at the upper end of Burrard Inlet which have been long abandoned, and whose names my informants could not recall. My enumeration contains in all some ninety-three villages, each of which, according to Chief Thomas of Qē'qīōs and others, was formerly a genuine Sk·qō'mic *ō'kwumūq*, containing from fifty to several hundred inhabitants.

On Sk·qō'mic River.

Right Bank.

Çō'tais.
N'çai'tc.
T'k·takai' = vine-maple.
SQāqai'Ek.
Kwāna'ken = hollow in mountain.
Yū'kuts.
Stō'toiī = leaning over (a cliff).
Kōmps.
Slōkoi.
N'k·u'kapenatc = canoes transformed to stone (see story of Qais).
K·wo'lān = ear.
Kau'ten.
Qē'qīōs.
Sīē'tcEm = sandy.
N'pōk·wis.
Ēk·ūks.
Tcīā'kamic (on creek of that name).
Tōktā'kamai = place of thimble-berries.
Spāpa'k·.
Ētlē'uq.
'Skaui'can.
Pōīa'm.

Left Bank.

S'k·lau' = beaver.
Stā'mis.
Smōk·.
Qā'k·sinē (on Ma'mukum Creek).
K·īāke'n.
Ikwo'psum.
QEk·wai'akin.
Ītlī'ōq.
Pō'kaiō'sum = slide.
Sk·ūmi'n = keekwilee-house.
Cēmps.
Tcimai'.
Tcuk·tcuk'ts.

Howe Sound.

West Side.

Tcē'was.
Swī'at.
Çē'tuksEm.
Çē'tūsum.
Kwi'tctenEm.
K·ē'kElun.
K·ōē'kōi.
Stcink· (Gibson's Landing).
Cīcai'ōQoi
QE'lkEtōs = painted.
Sk·u'tuksEn = promontory.
Ku'latsEn.
N'pā'puk·.
Tumtls = paint.
Tcākqai.
St'o'ktoks.
Stcilks = sling.
Kē'tlals'm = nipping grass, so called because deer come here in spring to eat the fresh grass.
Skē'awatsut (Point Atkinson).

East Side.

K·ūkutwō'm = waterfall.
Çē'tsākEn.

Islands in Sound.

Tlā'qōm (Anvil Island).
Tcā'lkunts (Gambier Island).
Qōlē'laQōm (Bowen Island).
Sau'qtitc (Hat Island).
Mī'tlmetle'ltc (Passage Island).

English Bay, The Narrows, Burrard Inlet, and False Creek.

From Coal Harbour to Mouth of North Arm of the Fraser.

Tcetcē'lmen.
ṬcEkō'altc.
Pâpīāk· (lighthouse).
QoiQoi = masks.
Suntz.
Sk·ē'akunts.

Tcānts.
Sqēlc = standing up ('Siwash rock').
Stētūqk·.
Hēlcen = sandy beach; *verbatim*, soft to the foot.
Snauq (False Creek).
Sk·ōātcai's = deep hole in water.
Sk·wai'us.
Īa'lmuq (Jericho).
QapQapētlp = place of cedar (Point Grey).
U'lk·s'n = point (*cf.* radical for nose).
Tle'atlum
Tcitcilē'Ek.
K·u'laqEn.
HumElsom.
Mâli.

North Side from Point Atkinson, through the Narrows, up the Inlet

'St'k·qē'l.
SmElā'kōā.
K·'tcā'm.
Swai'wī.
Hōmu'ltcison (Capilano Creek) (former headquarters of supreme chief of the Sk·qō'mic).
TlāstlEmauq = Saltwater Creek.
Stlāu'n.
Qotlskaim = serpent pond.
Qōā'ltca (Linn Creek).
TcētcilQōk (Seymour Creek).
K·īāken = palisade, a fenced village.

Social Organisation.

The social organisation of the Sk·qō'mic has been so much broken up and modified by missionary and white influence that it is difficult now to learn any details about it. The tribe appears to have been divided, like the N'tlaka'pamuQ, into a number of *ō'kwumūq*, or village communities, each of which was governed by its own local chief. I could gather nothing of their beliefs with regard to the origin of their different villages: they seem to have none or else to have lost or forgotten them. Of the origin of the tribe as a whole and some of the chief events of their existence I gathered an account a few years ago from an ancient member of the tribe, who was born a year or so after Captain Vancouver's visit to them in 1792. This was published in the 'Proceedings of the Royal Society of Canada,' 1897–98. Briefly it tells how the first Sk·qō'mic man came into existence; how later the tribe was overwhelmed by a flood, and only one man and his wife escaped in their canoe, which landed on the mountains contiguous to the present Sk·qō'mic territory; and how later again a severe and prolonged snowstorm caused, by cold and famine, the death of the whole tribe save one man and his daughter. From these two the Sk·qō'mic trace their tribal descent.

The people were divided into the usual threefold division of chiefs, nobles, and common people. The lines, however, between these classes were not absolutely rigid. According to my informants a member of the lower class, if a woman, could rise to the class above her by marriage with a member of that class, the wife usually taking the rank of her husband if not a slave. But a man of the lower rank, even if he succeeded in marrying a woman of the middle class, could only become a member of that class by undergoing a long and severe training, in which daily washings and scrubbings of the body played an important part. This was evidently a form of initiation the further particulars of which I could not learn. As a rule the chiefs and their families and immediate relatives formed a class or caste apart, the title of chief or headman descending from father to son, patriarchate prevailing among the Sk·qō'mic. Consequently a chief usually married a chief's daughter or daughters. But this rule was sometimes broken, and a woman of a lower class was taken to wife. In these cases the chieftainship would properly descend to one of the chief's brothers or his son, and not to his own son. This was the rule. But it was possible to break this also and transmit the headship of the tribe to his own son by giving many 'potlatch' feasts,

and thus securing the goodwill of the tribe in his son's favour. The son, too, upon his father's death, would also give a feast and make handsome presents to all the influential men of the tribe, the result of which would be that he would be elected to the rank of chief, and be allowed to succeed his father in the chieftaincy of the tribe. From this it would seem that children took their social rank from their mother rather than from their father, which looks like a trace of matriarchate, or mother-right. It is clear from their folk-tales, however, that these class divisions were not hard and fast, but that members of a lower caste could by the performance of certain acts pass into that above it. Of secret societies I was unable to obtain any information whatever, and whether such formerly existed among the Sk·qō'mic—of which I am extremely doubtful—it seems impossible now to say. Among the chiefs there were some of higher rank than the others, as among the N'tlaka'pamuQ. The supreme *sīā'm* of the tribe was known by the title *Te Kīāpīlā'nōq*, and had his headquarters at the mouth of the Hōm'ultcison Creek, now called Capilano by the whites. He was local chief also of the Hōmu'ltcison sept. Next in rank to him came one of the Skuamish River chiefs. He likewise had a proper title, being known as *Te Qātsilā'nōq*.[1] I was unable to learn what special signification these titles had. It is possible we may see in them the special names of two powerful gentes. The gentile system of the Sk·qō'mic, if such existed, is not at all clear. The distinction between what might be regarded as a gens, or a sept, or a mere tribal division is very difficult to determine.

I could gather nothing satisfactory from any of my informants on this head. Heraldic and totemic symbols, according to some of them, were never used in the old days; but yet I was informed by others that some of the old houses had carved posts or columns, and that the figure of a bird or some other animal would sometimes be placed on a pole in front of the house or fastened to one of the gable ends. They also, sometimes at least, used masks in certain of their dances, if we may rely upon the information on these points in their folk-tales. The tribe, as my ethnographical notes show, was formerly divided into a number of subdivisions, or *ō'kwumūq*. Whether each of these should be regarded simply as a tribal subdivision, as among the N'tlaka'pamuQ, or as a gens, as among the northern tribes, is doubtful. Each division had its own proper name—in every instance, I think, a geographical one—derived from some local physical peculiarity, exactly as among the N'tlaka'pamuQ. In every *ō'kwumūq* there existed the same threefold division of the people into three classes, and in some instances the total number of souls in each village would amount to several hundreds. Generally speaking, each community would be made up of several families or clans. The members of these clans were not bound together, as the gentes of the northern

[1] The distinctive part of this title bears a remarkable resemblance to the esoteric term by which one of the Nootka deities was invoked by the chiefs of that tribe. Dr. Boas has recorded the name of this being under the form *Kā'tse*. The two forms so clearly resemble each other as to suggest some connection between them; and in this connection I may remark that the more I extend my studies of the Salish and Kwakiutl-Nootka, the stronger is the conviction forced upon me that between these two stocks there is a deeper underlying racial connection than the structural differences of their language would seem to indicate. Morphologically speaking, they seem to have little in common; but that little steadily increases with our larger analytical knowledge of their languages, and their vocabulary resemblances are many and far-reaching.

tribes, by common totems or crests. They comprised the blood relatives of any given family on both sides of the house for six generations. After the sixth generation the kinship ceases to hold good and the clanship is broken. Under this arrangement an individual's relatives were legion, and he would often have family connection in a score or more different *ō'kwumūq*. Among the present Sk·qō'mic almost all of them are related in this way to one another, and their cousinships are endless and even perplexing to themselves. Marriage within the family or clan as thus constituted was prohibited, but members of different clans in the same village could intermarry with each other. If each village community is to be regarded as a separate gens having a common origin from some common ancestor—which I think is extremely doubtful—then marriage among the Sk·qō'mic was not forbidden to members of the same gens. For my own part I am disposed to regard these separate communities as mere subdivisions of the tribe which were effected at different periods in their tribal existence, and generally, probably, from the same causes which have all over the world led to the founding of new homes and new settlements, viz., increase and stress of population. The evidence in favour of regarding these divisions as distinct gentes having each a separate origin and springing from a separate ancestor, as among the northern tribes, is scanty and doubtful. This view is strengthened by the traditional origin of the tribe, which makes them all spring from a common pair. I do not desire to be understood as asserting that totemic gentes did not formerly exist among the Sk·qō'mic, as Dr. Boas seems to hold. All I say is that after diligent inquiry from several of the chiefs and others I could myself find no evidence of it. I could not learn that any particular group or family bore names peculiar to that group or family, or possessed privileges not shared by the others other than the right to certain dances and their accompanying songs the origin and source of which was some personal dream, or vision, or experience of their own or their parents. But the ownership of these dances differed in no way from the ownership of a canoe or any other piece of property, and constituted no kind of bond or union between the owner of them and others of the tribe or *ō'kwumūq*.

The only peculiar name that I could learn other than those of the supreme chiefs was that borne by the offspring of female slaves by their masters. This was the term *s'tā'cEm*, and was a word of reproach.

Polygamy was commonly practised among the Sk·qō'mic, the number of a man's wives being limited only by his rank and wealth. A chief would frequently have four or five wives. Each wife had her own quarters in the house, which included a fire and a bed of her own. A favourite wife would rank first. She would be regarded in consequence with jealousy and hatred by the others. The husband would sometimes eat with one, sometimes with another. Infidelity in wives was punished by cutting the soles of their feet, or, in some instances, by stoning them to death.

Mortuary Customs.

The burial customs of the modern Sk·qō'mic are now commonly conducted in the same way as our own, few, if any, of the older ceremonies, which are discountenanced by the priests, being observed. In former days the following customs were universally practised :—When life had left the body the corpse was taken out of the house and washed by some

elderly friends of the family. It was then doubled up and placed in a box coffin before it had grown rigid. In the case of chiefs the body was sometimes placed in a canoe instead of a box. It was then taken to the burial-ground whether it were day or night. If it were night-time torches would be used. The box containing the corpse was then placed in a roughly constructed cedar-slab shed, after which everybody returned home. The immediate relatives of the deceased followed the corpse, accompanied by the other members of the family or clan, together with all their friends, and a band of special mourners, who are engaged for the occasion. All those who followed the corpse to the graveyard must paint the breasts of their garments with red paint. If this were not done a scarcity of fish would be the result at the next salmon run. The mourners are of both sexes, and all cry aloud. The period of mourning lasted generally about a month. If, however, the deceased were very dear to the survivors, the mourning would be kept up longer. When a chief died the whole community turned out to mourn, and almost everybody followed the corpse. The hired mourners are paid for their services with blankets or skins. If the friends of the deceased are wealthy a feast is held immediately after the disposal of the body, and the mourners are then paid. If, however, the relatives of the deceased are poor, then no feast is given at the time, and the payment of the mourners is also deferred until such occasion as a sufficient number of blankets and skins has been collected, and they are in a position to hold the feast. It was customary to choose the occasion of some big 'potlatch' gathering, when everybody would be present.

When the relatives of the deceased have returned from the graveyard they burn cedar (*Thuya gigantea*) and salal-berry (*Gaultheria Shallon*) branches and whip the whole dwelling with boughs, particularly that part where the body lay, to drive away the presence of death, sickness, and ghosts, all of which are supposed to linger there.

Some three or four days after the burial it was not unusual for the witches and wizards of the tribe to declare that the ghost of the dead had returned from the land of spirits for something to eat. The relatives of the deceased are informed, and they immediately gather all the best food they can procure, and take it, sometimes to the burial-ground and sometimes into the woods, and spread it out on a big blanket made from the wool of the mountain sheep or goat. The witches and medicine-men now invite the shade of the dead to eat. Presently they assure the relatives that the spirit is satisfied. The food is then either distributed to the poor and old, or else it is consumed in a fire built for the occasion.

The customs to be observed by the immediate survivors of the deceased differ somewhat according to sex. If a woman had lost her husband she must fast for one whole day. At the close of the day a neighbour would bring in a large piece of dried fish. The widow must now bite four mouthfuls from this piece of fish, while it is held in the neighbour's hands, without touching it herself except with her mouth. After she had eaten her four mouthfuls of fish she might partake of other food, but must be careful to abstain from eating it before her children. Should the food be eaten in the presence of the children it was believed that they would all shortly die, the act being regarded as equivalent to 'eating up their life.' This rule must be strictly observed for the space of a month. For the same period she must bathe the first thing every morning and scrub her body with boughs, after which she must blow on

the tips of her fingers four times successively if she desired to get stout or fat, and if she wanted to become thin she must suck in the air from the tips of her fingers the same number of times. Another practice she must observe was to place *tsutzētcai'ē* (spruce-boughs) under her bed, and also hang some at the head of it.[1] She must also eat her food off these boughs for at least a month. The widow always accompanied the corpse of her husband to the burial-place. Her blanket is painted for the occasion with streaks of red paint, as is also the crown of her head. Excessive weeping sometimes made her so weak that she had to support herself with a staff (*t'tcātc*) while walking to and from the graveyard. The customs to be observed by the widower were simpler. He must likewise bathe every morning at daybreak, and must also abstain from eating before his children for the space of a month; but his head was not painted, only his blanket; and he puts the *tsutzētcai'ē* only at the head of his bed, and not under it. Some three or four days after the burial all the relatives of the deceased, except the widow or the widower, must cut their hair. The severed hair is always carefully collected and buried. After the ceremony of hair-cutting is over all those who have attended the funeral go in a line to the river or the inlet, according to the locality, and walk down into the water till it is up to their breasts; then at a word they all dip together once and come out again. If they are wearing blankets at the time they cast these aside, but otherwise do not trouble to disrobe.

It was customary for widows and orphans some time during the mortuary rites to take a small white pebble and roll it in their mouths four times. This was supposed to prevent the teeth from decaying.

Birth Customs.

It was customary among the Sk·qō'mic women to retire to the woods when they were about to give birth to their children. Usually a woman went quite alone or accompanied only by her husband. Midwives were called in for the first child, but afterwards only in cases of difficulty or when the labour was unduly prolonged. Usually the woman would fulfil her daily duties to within an hour of the child's birth, and be ready to take them up again a few hours afterwards. In the case of first children parents of standing would engage three or four midwives or experienced women for the occasion. Each had her own special duties to perform. These were prescribed by long-established custom. It was the office of one to sever the umbilical cord and dispose of the after-birth; of another to watch and care for the baby; and of another to 'cook the milk' and generally look after the mother. They were paid for their services immediately after the event by the husband with gifts of blankets. This honorarium was also prescribed by usage, the number of blankets given on the occasion depending on the husband's social position. Immediately after the birth of the child it is washed all over in cold water and then wrapped in the softest *slo'wi* (inner bark of the cedar—*Thuya gigantea*—beaten till soft and fine) and placed in a cradle of cedar-wood. This cradle was constructed in the following manner:—A piece of cedar-wood about thirty inches long and ten or twelve inches wide, was first taken; a second, and shorter, but considerably broader, piece was then bent over this in the form of an arch, and fastened in this position to the longitudinal edges of the other, thus forming a kind of pocket. The lower piece,

[1] The object of this was to preserve her from her husband's sickness.

or bed of the cradle, extended about four inches beyond the other at the foot, and about six inches at the head. The extension at the foot was bent upwards till it reached an angle of thirty or forty degrees, and fastened in this position to the upper piece by lacing. This formed a kind of foot-board the object of which was to keep the baby from slipping down out of the cradle and allow at the same time the liquids to escape. The head of the cradle was left open. The child passed the first year of its life in this receptacle, never leaving it except to be washed twice daily. It was both fed and dandled in its cradle. If the mother had outside work to do, the cradle was usually slung to her shoulder or to a swing-pole. In carrying it the weight was borne on the hip. It was during this cradle existence of the child that the cranial deformation formerly practised by this tribe took place. This was effected by frontal pressure, pads or bands of *slō'wi* being tied across the anterior part of the cranium and held there by thongs fastened to the bottom of the cradle. A pad was also tied across the top of the head about the line of the coronal suture to prevent the head from rising to a ridge here, as was common among the Siciatl tribe, the Sk·qō'mic regarding this as ugly and unsightly. The immediate effect of this pressure was threefold. It caused a flattening of the occipital region by contact with the cradle-board; it gave a peculiarly receding sweep to the frontal bone, a line of beauty in Sk·qō'mic eyes; and it produced a compensatory bulge of the head laterally; the general effect of all which was to make the head appear abnormally short and the face unusually broad. This practice of cranial deformation has now, I believe, been wholly given up by the Sk·qō'mic, though the infant still passes the greater part of the first year of its existence in a cradle as formerly. On one of my visits to the Sk·qō'mic I observed an Indian mother nursing her baby in a rush-made cradle with open top. This, I was informed, was the style now commonly used. Should the birth take place in the winter, or when it was not convenient for the mother to retire to the woods, a temporary screen of reed mats would be put up in the general dwelling, behind which the woman would give birth to her child. A very peculiar custom obtained among the Sk·qō'mic in the case of first-born children. The mother might not feed the child from the breast for four days. Her breasts must first be steamed with a decoction of the rind of the elderberry (*Sambucus racemosa*), and then covered with poultices of the same material. This was kept up for four days, its object being to 'cook' the mother's milk. The process, called in the Sk·qō'mic *wu'tlkwai mīūkwum*='cooking the breast,' was sometimes repeated at the birth of the second child, only on this occasion the infant was not deprived of the breast. It was thought that the mother's milk was harmful to the child before the fourth day and before it had been 'cooked.' This strange custom amongst others may perhaps have had something to do with the high death-rate among the old-time children. In earlier days, before contact with the whites, it was not at all uncommon for a mother to give birth to a dozen children; but there were few households which contained a family of children of more than half of that number. It is true female children were commonly strangled at birth if there were too many girls in the family. This unnatural practice was effected by the parents themselves—usually by the mother—by stopping the nostrils and placing a gag of *slō'wi* in the child's mouth. My informant was herself doomed to this fate at her birth, and was only spared at the earnest solicitations of an elder sister.

After the birth of the child, when the woman had passed the after-birth, she was taken or went down to the river or inlet and bathed in the icy-cold water, no matter what time of year or what kind of weather it was. My informant stated that she had been thus taken to the river and washed all over after the birth of her first child in the month of January, when the water was covered with ice and the ground with snow. Ablutive ceremonies played a very important part in the lives of the old-time Sk·qō'mic, as we may easily gather from their old customs. Men, women, and children bathed constantly. Among the young men it formed an important feature in their training. Each sex had its own special bathing place, men and women, or boys and girls, after childhood never bathing together.

The birth of twins was a very special event, twins always possessing, it was believed, supernormal powers, the commonest of which was control of the wind. It would seem that the birth of twins was usually presaged by dreams on the part of both parents. In these dreams minute instructions would be given to the parents as to the course they must pursue in the care and up-bringing of the children. These they must follow implicitly in every particular. If they were neglected it was thought and believed that the twins would die. If the event took place in winter a fire must be built in the woods, but the husband must on no account touch or have anything to do with it.[1] Immediately after the birth both husband and wife must bathe in cold water, using the tips of spruce, fir, and cedar branches to scrub themselves with. After this they must remain in seclusion, apart from the rest of the tribe, for a month. Any breach of this rule was regarded as a grave offence, which was bound to bring severe punishment upon the offenders. The hair of twins was supposed never to be cut. If for any reason this rule was departed from, great care had to be taken to bury all that had been cut off. Neglect of this, it was believed, would bring about a severe winter. Throughout the whole childhood of the twins the greatest care had to be taken of them. If at any time wind was desired for sailing, the bodies of the twins would be rubbed with oil or grease, after which, it is said, the wind would immediately rise. The *tsai'anūk*, a kind of small fish which I was unable to identify, and which periodically visits the Sk·qō'mic River in large numbers, are said to be descended from a pair of twins (see the story of the origin of the *tsai'anūk* below, under 'Folk-lore').

When a woman desired to give birth to a son she would place during her pregnancy a bow and arrows under her bed. If a daughter were desired a needle and some of the utensils used in weaving would take the place of the bow and arrows. Another custom to ensure the same end was for the woman to chew, in the early days of her pregnancy, the leaves of certain kinds of willow and other shrubs. These leaves were distinguished as 'male' and 'female' leaves.

Customs practised to prevent Pregnancy.

When a woman desired to bear no more children she adopted one or more of the following practices. She would get out of bed immediately after giving birth to her child and stand for some time up to her armpits in the icy cold water of the inlet, or river, or sound, according to her locality; or she would bury the after-birth on the beach at ebb-tide just

[1] If the husband built the fire a very cold period would follow.

the line of land and water. Another practice was to hang the after-birth on the branch of a tree and keep it there for a twelvemonth. Still another was to turn round three times and kick the after-birth before it was disposed of. Usually the mode of disposing of the after-birth was by burying it secretly in the ground. Among the Sk'qō'mic it was never burned, as among some tribes. It was believed that the mother would 'swell up' and die if the after-birth were burned. It is said that a woman once destroyed the after-birth in this manner with this melancholy result; hence its disposal in this way was ever afterwards most carefully avoided.

Marriage Customs.

Formerly, when a young man took a fancy to a girl and desired to make her his wife, the custom was for him to go to the house of the girl's parents and squat down with his blanket wrapped about him just inside the door. Here he was supposed to remain for four days and nights without eating or drinking. During this period no one of the girl's family takes the slightest notice of him. The only difference his presence makes in the house is to cause the parents to keep a bright fire burning all night. This is done that they may readily perceive that he takes no advantage of his proximity to the girl to make love to her or otherwise molest her during the night. On the fourth day, if the suitor is acceptable to the parents, the mother of the girl asks some neighbour to acquaint the youth that they are willing to accept him as their son-in-law, and give him the girl. To himself they still say nothing, nor in any way take the slightest notice of him; and as no communication of any kind can take place between the girl's people and the young man at this stage of the proceedings, this neighbour now cooks a meal for the fasting lover and informs him at the same time that his suit is acceptable to the family, and that the girl will be given to him in the usual way.

After the young man's acceptance by the girl's parents in the manner described the youth would then return home, and in a few days come back for his bride, accompanied by all his friends and relatives. If he were just an ordinary young man of the tribe, of no particular standing, he would bring with him one canoe-load of blankets; but if he were a person of rank, such as a chief's son, he would bring two canoe-loads of blankets with him. These he would distribute to the bride's relatives. He and his friends are now entertained for the rest of the day by his prospective father-in-law, and accommodation is afforded them for the night, the inmates of the house sleeping on one side of the building and the visitors on the other. On the following morning, after a good meal has been indulged in, all go down to the beach to where the bride-groom's canoe is moored, the parents of the bride taking with them a number of blankets, which they put in the canoe. If the bride is a person of rank the whole course from the house to the beach is covered with a line of blankets for her to walk upon, and two old women, as maids-of-honour, lead her down to the canoe. The bride is dressed for the occasion in all the bravery of bright-coloured blankets and what other ornaments she may possess. Over her head, completely enveloping her, a blanket is thrown as a kind of bridal veil. Behind her come the female slaves of her father's household, carrying all her personal belongings, such as mats, baskets, blankets, wooden platters, spoons, &c. The bridesmaids now place the bride in the bow of the canoe, after which etiquette demands

that the bridegroom shall reward them for their services by a gift of one or more blankets each. When this has been done the parties separate, the girl's family and friends going back to the village, and the youth with his bride and friends returning home. If the girl were the daughter of ordinary parents she would have to dispense with some of these ceremonies, such as the walking on blankets, &c. Some days later the bride and bridegroom and his friends return to the bride's old home, where a feast is held. After the feast is over they separate again, and some time later the girl's parents and friends pay a return visit to her husband's home, bringing with them blankets and other presents equal in number and value to those bestowed upon themselves. These are distributed to the son-in-law and his friends, after which all partake of a second feast, which closes the marriage ceremonies, and thereafter the girl and youth are regarded by all as man and wife.

Sometimes the suitor is not acceptable to the girl's parents, and after a family council has been held he is rejected. A friendly neighbour is called in as before to act as intermediary and convey to him the decision of the parents, only on this occasion she provides no meal for him. If the youth has set his heart on the girl he will now try and induce her to elope with him. If she refuses to do this, he has perforce to give her up and seek a wife elsewhere. If, however, she consents, he seizes the first opportunity that offers and carries her off to the woods with him, where they remain together for several days. If the objection to the young man on the part of the girl's parents is not deep-rooted, he is now permitted to keep the girl as his wife on payment to them of a certain number of blankets. If, however, they object even now to have him as a son-in-law, they take the girl from him, and it is understood on both sides that he is to trouble her or them no further.

With regard to the suitor's fast of four days and nights I questioned my informant whether the old-time youths of the tribe really and truly abstained from food and drink on these occasions. He assured me they undoubtedly did, and that it was a matter of honour with them to eat or drink nothing during the whole period, the significance of their abstinence being that they were now men, and could readily endure the hardships and privations incident to manhood. Apropos of this custom he related to me an instance of what befell a certain luckless youth who sought surreptitiously to break his fast. The family of the girl whom he sought to take as wife had all gone out on the third day, leaving him squatting in his place by the door. They had gone across the inlet to pay a visit to a village on the other side. The absence of the whole family tempted the famishing youth to take advantage of his temporary opportunities to satisfy the cravings of his stomach. So he left his post and ran down to the beach and hastily dug up some clams. As he was in the act of eating these a little girl told him that the family was returning on the water. In his haste to eat the clams he had prepared he swallowed one whole, and it stuck in his throat and choked him so that he died. His melancholy end was regarded by everybody as richly deserved, aad his fate was held up thereafter as a warning to succeeding generations of young men.

These customs are no longer kept up among the great body of the Sk·qō'mic. Marriages among them are now conducted very much after the manner of the whites and solemnised by the priest. A few of the heathen Sk·qō'mic, who still hold by their old tribal customs, continue to

marry their daughters in this way; but these are few in number, and, generally speaking, the marriage customs as here described are only a tradition in the tribe.

Naming.

A child usually received no name in babyhood, but when about three years old the elders of the child's family or clan would choose a name for it from among those of its ancestors. This name it would bear through life if a girl, but if a boy, and the son of some person of rank and wealth, some years later his parents would give a 'potlatch,' and then he would receive a new name. This was quite commonly that of his own father or of his paternal grandfather, whether they were alive or dead.

The names of dead people were tabooed. That is to say, it was a breach of custom and good manners to mention the name of a dead person in the presence of the deceased's relatives or connections. This custom gave rise to inconvenience at times. It was quite common for men to be called by the name of some implement or utensil. An individual once bore the name of Sk·u'mEl = 'paddle.' When he died, as they might not use this term before his relatives, they had to make use of the term *qautlīwus* when they wished to say 'paddle.' I did not get the signification of this new term. Another person bore the name *Sluk·cEn*= 'moccasin.' When he died a new word had to be coined, and to-day both terms are in common use for moccasin.

The stories give us examples of the names used formerly. I append a few specimens of these here:—

Tcīa'tmuq = owl.	Cauk· = skull.
Qoitcītā'l.	SQēils = copper.
Â'tsaian.	Çukçuklaklō's.
Sīa'tlmEQ = rain-man.	Tētkē'tsEn.
TculQ.	

Puberty Customs.

When a girl arrived at puberty she would call her mother's attention to her condition. The mother at once informed the father, who calls the family and relatives together. They discuss the matter and arrange what course the girl is to follow.[1] First of all they take two strands of the wool of the mountain sheep or goat and tie them to her hair, one on each side of her forehead. This is a public notification of the girl's condition, which everybody understands. She is now set to 'pull' wool or hair without food or drink for the space of four days. She was kept without water during this period, because it was believed that if she drank water when in this condition she would spoil her teeth. She must abstain from washing or bathing, and must never go near the fire during the four days.[2] When in this condition her mother, or grandmother, or some other woman would pull out all the irregular hairs from the edges of her eyebrows so as to make them fine and even. The denuded parts were always rubbed with the girl's saliva to prevent the hairs growing again. When the four days were up some old women would take her in hand, and bathe her head and body in hot water, and scrub her with

[1] From this statement it would seem that no two girls necessarily followed the same procedure.

[2] It was believed that if she sat near the fire during her menses her skin would become red, and ever after remain in that condition.

branches till her skin was almost torn off and her body was sore and covered from head to foot with scratches from the severe treatment she had received. The prickly brambles of the trailing blackberry (*Rubus sp.*) were often employed for this purpose, and my informant told me that it was no uncommon thing for a girl to toss and turn in agony the night following this bath, unable to close her eyes in sleep for the pain and smarting of her body.

If she were the daughter of a chief or a noble she would be bathed by the *sqō'm'tEn* or *siū* (medicine man or woman). These would be paid for their services with gifts of blankets or skins.

The object of these heroic measures was to make the girl 'bright and smart.' After the bath she was given food and drink and permitted to come to the fire. Sometimes a friend of the family would mark the occasion by putting a nice new blanket over the girl's shoulders. After her meal her face would be painted with streaks of red paint, and the girl would then go to the forest and pull down the branches of all the cedar and spruce trees she passed and rub her face and body with their tips, and then let them spring up again. The object of this practice was to make her charming and attractive in the eyes of men. She would also take a quantity of fern-roots of the edible kind (*Pteris aquilina*) and offer them to the biggest trees she could find. This was supposed to give her a generous nature and keep her from becoming stingy and mean.

After a girl had arrived at puberty she was never allowed to play or mingle with the boys. She was kept indoors at work all day long. The lot of a girl among the Sk·qō'mic in the olden days does not appear to have been an enviable one.

A girl or woman during her monthly periods was 'bad medicine;' that is, she was supposed to carry ill-luck with her. If she entered a sick-room the invalid was sure to get worse; and if she crossed the path of a hunter or a fisher he would get no luck that trip.

When people were sick they were rubbed with dog-fish oil.

When the screech-owl (*cai'u*) was heard hooting around a house it was regarded as a sure sign that some of the inmates would shortly die. *Cai'u* signifies 'ghost,' or 'shade.'

Dwellings.

The dwellings of the old Sk·qō'mic were of the communal kind, whether they were the ordinary slab and cedar-board structure or whether they were the winter keekwilee-house. As far as I have been able to gather, only the upper tribes on the Sk·qō'mic River used the *sk·umi'n*, or keekwilee-house. That this structure was known to them is clear from the name of one of their villages, which signifies in English 'keekwilee-house.' The lower tribes commonly used the cedar structure all the year round. Each village contained one and sometimes two of these placed at right angles to one another, or in parallel lines according to the local peculiarities of the village site. Some of them, in the more populous villages, were of enormous length, extending in an unbroken line for upwards of 600 feet. Houses of two or three hundred feet in length were very ordinary dwellings. In width they varied from 20 to 40 feet. The walls, too, were of variable height, ranging from 8 to 15 feet when the roofs were gabled. If the roof contained but one slope, then the higher side would rise to 25 or even 30 feet. Both sides and roof were built of cedar boards or slabs split with hammer and wedges

from the cedar trunk. The cedar (*Thuya gigantea*) of British Columbia lends itself readily to operations of this kind, and the task is not as difficult as might be imagined. The white settlers almost everywhere build their houses, stables, fences, and barns of cedar split by themselves in this way. I have seen boards split out as smooth and uniform as if they had been cut out with a saw and planed. In the native dwellings the boards were held in place by withes or ropes made from young cedars or from the branches of older ones. There were no windows in these buildings; sunlight and air came in through the doors or by the roof, a part of which was pulled down a few feet to let the smoke out and the air and light in during the day in fine weather. These structures are open from end to end without partitions or divisions of any kind. The chief quite commonly occupied the centre of the dwelling. Next to him, on either side, came his brothers and other notabilities, and beyond these the baser folk. Each family had its own allotted space at the side of the dwelling and its own fire. This space was commonly just ample enough to allow of the beds of the family being arranged around three sides of a square with an open front towards the fire and centre of the room thus . The bed was raised by a kind of platform or bed-stand about two feet from the ground. In the space beneath were stored roots and such-like commodities. Above and over the beds shelves were hung. On these were stored the dried fish and utensils of the family. If the family were one of position and wealth, several large cedar boxes would be found lying about. These would contain the blankets and skins and other valuables of the owners. To separate the beds of one family from another, hanging curtains of grass and reeds were suspended on either side, but the front was left open. The beds of the Sk·qō′mic consisted of reed mats and *slō′wi*, i.e., the inner bark of the cedar beaten till fine and soft. Rolls of the same material formed their pillows. Their coverings were, for the poorer class, mats of the same materials. For the wealthy these were supplemented by mountain-goat blankets and dressed deer-skins. The Sk·qō′mic husband and wife did not sleep side by side, but feet to feet. If the bed space was confined the feet of one would reach to the head of the other; but usually this was not the case, plenty of room being allowed.

In winter it was customary to keep the fires burning all night, large logs being placed upon them for the purpose. On the occasion of feasts and dances the hanging mats about the beds would all be taken down, the beds themselves serving for seats or platforms for the drummers and spectators.

Household Utensils.

The Sk·qō′mic housekeeper possessed cooking pots of both cedar and basketry. Food was served in large shallow cedar troughs or dishes. Smaller platters of the same material were also in use, likewise spoons, though these were also made of horn. When eating they sat on mats or squatted on their haunches. Of baskets they had a great variety. Some of these were made from the split roots of young cedar, spruce, or fir trees, others from the bark of the alder and birch.

Dress.

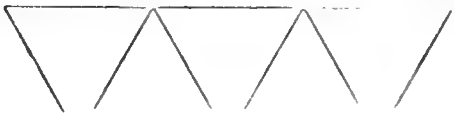
The dress of the Sk·qō′mic in præ-trading days did not differ materially from that of other tribes of this region. The men commonly wore high

leggings and waist-cloth. Over their shoulders, when they were not actively engaged, they wore, toga-fashion, a native blanket. The women of the nobler class wore a dressed deer-skin shroud or smock, which reached from the shoulders to below their knees; inferior women wore only short petticoats of woven *slō'wi*. Moccasins were worn at times by both sexes. The women sometimes covered their heads with a plaited conical hat with broad sloping brim. This served also as a receptacle for berries and other small things if no basket were at hand. The exterior of these hats was commonly figured in red and black paints or dyes. Some of the older women may still be occasionally seen wearing them, but they have gone out of use generally.

Tattooing and Painting.

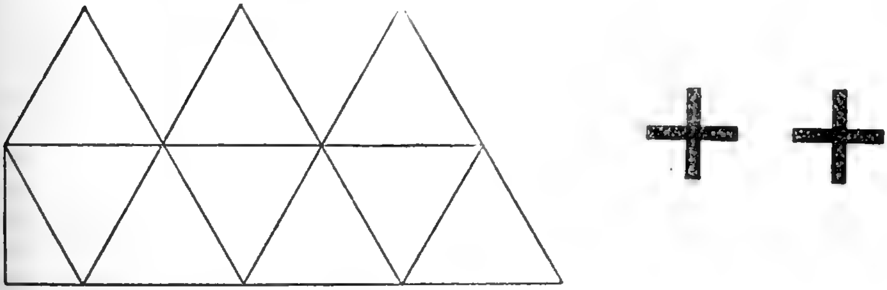
In earlier days the men used to paint themselves for dancing and other ceremonies. I could not learn that the men ever tattooed their bodies. A favourite decoration was that effected by sprinkling particles of mica over their faces and bodies upon a groundwork of grease. This gave

Markings on right arm above back of the hand.



Colour blue.

Markings on left arm above back of the hand.



Colour blue.

their bodies a glistening appearance. They obtained the mica for this purpose from disintegrated granite. The women commonly employed a kind of red clay for facial decoration. This they smeared over their cheeks, chins, and foreheads. When confined only to the cheeks and not too lavishly put on the effect was not displeasing to the eye. It gave them a ruddy, comely appearance. The old women of pagan habits still decorate themselves in this way. The women were accustomed to tattoo themselves on the arm or wrist and lower leg. The markings were always simple and generally crude, bearing no resemblance whatever to the elaborate and fanciful designs of the Haida and other northern Indians. A copy of the markings on the arms of one of my informants. is given above.

Games.

The Sk·qō'mic had a variety of games. I obtained some information on some of these. The commonest and most popular were the ball games

Of these they had two called *k·ē'k·qua* and *tcqui'la*. The former was a kind of lacrosse, and the ball was caught and thrown with an instrument similar to the lacrosse stick. The other was a kind of football. They played also a game called *tckwīē'*. This was a kind of shuttlecock and battledore, and a favourite pastime of the girls. They were acquainted also with '*qauwi'lts*,' or the 'cat's-cradle' game. But dancing and dramatic impersonations of animals were their favourite pastimes, and these played an important part in the tribal festivities in earlier days.

Dances.

The Sk·qō'mic had three kinds of dances, called respectively *mē'tla*, *kō'qok·s*, and *skaip*. The first was the common dance, which any one could perform; the second was characterised by spasmodic shakings of the head on the part of the dancer; the third had for its distinguishing feature a shaking or violent trembling of the hand, which was held aloft in the air during the dance. In this dance the dancer spits much blood, or something which has the appearance of blood. I have not myself seen a dance of this kind, so cannot say whether it is really blood or not. As they appear to be none the worse after the dancing is over they probably do not spit blood. When dancing they invariably sing. These dance-songs are private property. No one can use another person's song unless permission has been given, or unless it belongs jointly to more than one person. These dance-songs are acquired by inheritance or they are learnt in dreams. Dreams or visions are the original source of all their dances. A person dreams of a certain dance, and on the next occasion introduces it. Not every one is a dancer; only those who are by mental temperament fitted for the part ever become noted dancers. The reason of this is simple. A dancer during the performance of his dance is not in a normal condition of mind. He or she is practically in a hypnotic trance state. On the occasion of a dance the dancers come forward as they are moved or prompted by self-suggestion or the mental suggestion of the waiting audience. They sit passive waiting for the 'psychological moment,' just precisely as do the sitters in a 'mediumistic circle.' The monotonous beating of cedar boards on all sides, which is their dance music, has the effect of sending some of them into hypnotic trances. First one and then another heaves a deep sigh, or utters sounds indicative of mental disorder; some swoon outright, and have to be brought to a dancing condition by the dashing of cold water over them; and some start off in a kind of frenzy, and dance from fire to fire all round the building till they fall exhausted from their exertions.

Dancers had to undergo a certain training. When young men or women desired to become dancers they had first to subject themselves to a four days' fast. In this condition it was easy for them to pass into the hypnotic state. In the case of the girls in particular they would invariably swoon away on the fourth night, when the dance would be held, and the *sqōm'tᴇn* and the *sīū* would work upon them to restore them to consciousness. Presently a girl would come out of her swoon with a deep sigh and begin singing, and then start off dancing for half an hour. This dance she is supposed to have learnt in her trance. When she has finished her performance she is driven out into the forest among the trees. The purpose of this is that she may learn a new dance from the bushes and trees, which they think are able to hold communication with the neophyte in her present state and impart to her some of their know-

ledge. After a while she returns to the building again and performs a new dance. When a novice performs his or her first dance it is called their *hausā'lktl.* Nearly all the spectators of the dances beat time with sticks on loose cedar boards placed on the beds. The movements of the dancers are various, agility and endurance being more aimed at than what we should call grace. Prancing like a high-stepping horse is a noted feature in some of the men's dances. An old resident of the district, Mr. Jonathan Miller, now postmaster of Vancouver City, but who formerly had much to do with the Indians in his capacity of provincial constable, informed me that at the close of one of their dances, which took place about thirty-eight years ago at the village of QoiQoi (=masks), in Stanley Park, which then had a population of 700, and now contains but one family, a noted medicine-man, or *sqōm'tEn*, gave a performance. He came into the circle with a small living dog in his teeth. As he danced he devoured the creature piecemeal. He bit the skin from its nose and tore it backwards with his teeth till he reached the throat. He then tore off piece after piece of the flesh and danced round the building, devouring it as he went. This dance was known as the 'dog-dance.' This is no longer practised even by the pagan bands, as far as I can learn.

There was a custom among the Sk·qō'mic of 'bringing out' a girl, not altogether unlike the custom among ourselves. In the case of a girl who had lost her mother when she had reached the age of puberty she was publicly 'brought out' at the next dance, and sang and danced her mother's song and dance before the whole community. She was attired for the occasion in a special garment or head-dress. When the people were assembled for the dancing an elderly man of the girl's family would proclaim aloud that So-and-so was going to dance and sing her mother's song. Her brothers or her cousins would now prepare and robe her. This ceremony was called *sō'yūmaitl*, and consisted in placing upon her head a kind of veil composed of tails made from the wool of the mountain-goat, which hung down all round her person, and bobbed and swayed as she moved. The garment was called *sō'yūmEn.* If the girl were a good industrious sister the brothers would show their esteem and regard for her by seating her on a pile of blankets, afterwards to be given away to mark the occasion. Usually the ceremony took place in the house, but sometimes a platform would be erected on several canoes joined together on the water, and the dance would take place there. When the announcement would be made of the dance all the people would show their pleasure by clapping their hands much as a white audience does. In earlier times the girl danced on a blanket, which was afterwards *sqāls*, or scrambled for by the onlookers, each wildly endeavouring to get a piece of it. Every one who secured a grip of the blanket was entitled to cut off all he held in his hand. These pieces of blanket were not prized as mere souvenirs of the occasion, as might be thought, but rather as precious material to be rewoven into another blanket. That is the reason why blankets at potlatches and other feasts were cut into pieces if there were not enough whole ones to go round among the guests. Mountain-goat wool was a valuable commodity, and not easy to secure ; hence the value of even a small piece of blanket. This *sqāls*, or scrambling, was always an exciting scene, and because of an accident that happened on one of these occasions to the *débutante* by the over-eagerness of the crowd to get at the blanket, it was afterwards

always suspended over the girl's head while she danced, and when she had finished it was taken down and thrown to the audience, who literally cut and tore it to pieces. In later times, after the introduction of Hudson's Bay blankets, the pieces secured from the *sqāls* of these were sewn together to make baby blankets of.

Potlatches.

The Sk·qō'mic in common with other tribes of this region were given to holding 'potlatches.' These have been so often described that it is unnecessary to give an account of them here. They were the occasion of great gatherings. Whole tribes from long distances would be invited sometimes. Representatives from Lytton and Kamloops in the interior, and from the upper coast and Vancouver's Island, were present on one occasion at QoiQoi. Over 2,000 in all sat down to the feast. An immense quantity of property was distributed on this occasion, estimated by Mr. J. Miller, who was present, to be worth over $5,000. On another and later occasion chief SemEla'no, the head of one of the confederated bands at the mouth of the Fraser, gave away $3,000 in silver and 2,000 blankets.

Wars.

The Sk·qō'mic would sometimes wage war with their northern neighbours the StlatlumH or Lillooets. They had also to defend themselves from marauding bands of Chilcotins, but their most dreaded enemies were the U'keltaws, a band of the Kwakiutl tribe. These latter were long the scourge of the coast from the northern end of Vancouver's Island to the Columbia, and from the mouth of the Fraser up to Yale. There is not a tribe on the Fraser that has not memories of evil times and bitter losses caused by the visits of this band. Only on one occasion is it recorded that the Sk·qō'mic got the better of their foes, and that since the white man's time and the advent of firearms. It is told that the Sk·qō'mic scouts brought timely warning of the approach of two war canoes of U'keltaws. The Sk·qō'mic at that time had a courageous and resourceful leader in their head chief Kīapila'noQ. He assembled a number of the bravest men and best shots of the tribe and hid them in a log hut built for the purpose at the mouth of the narrows leading into Burrard Inlet. On the flats immediately in front of the hut he placed some of the women and children, who were to pretend to be gathering drift wood. When the U'keltaws came into the narrows they at once perceived the women and children, and, thinking to secure these for slaves in the apparent absence of the men, they landed. The women and children now fled towards the woods, drawing their pursuers after them close to the hut. The hidden Sk·qō'mic now opened fire upon the U'keltaws and killed every one without harm to themselves. The very name of this band was a terror to the other tribes, and the mothers would frighten their children into silence and quiet by saying the U'keltaws were coming for them. In most of the villages they had palisaded enclosures to retire into when hard pressed by this enemy.

Food.

The principal and staple food of the Sk·ō'mic was salmon. These, fresh in season and dried out of season, were to them what bread is to the European and rice to the Oriental, and great was the distress and famine

if the salmon catch was poor. Their traditions tell of troubles of this kind occasionally. They also hunted the deer with dogs, and occasionally secured a mountain-goat or two. In hunting the deer they did not shoot or trap them. The dogs were trained to drive them into the water, where they were easily despatched by men in canoes. Some of the men were skilful with the bow and arrow, and secured by this means many duck, &c., but it was in fishing the tribe excelled. Fruits and roots of various kinds were also eaten by them. This we may gather for ourselves from their folk-tales. I was unable to secure the native names of many of these. Such of those as I did get will be found in my vocabulary of Sk·qō′mic terms below, with their botanical equivalents. I could not learn that any family or village had exclusive rights over fishing, hunting, or berry and root grounds. These seemed to be common to all alike. Neither could I hear anything of 'First Fruits' ceremonies as among the N'tlaka′pamuq and River Indians. The chiefs used formerly to pray for the tribe or village to Tᴇ tcītl sīā′m, the upper chief, but I could learn no particulars of these prayers. They have been in contact, more or less close, with white men for over two generations, and this intercourse, with the influence of the missionaries, has broken down and thrust aside many of their old pagan beliefs and practices, many of which are not known at all by the younger men and women, and almost forgotten by the older ones. Like the other tribes of this region they were fond of fish-oils, and particularly salmon-oil. They extracted oil from the sturgeon, the seal, the salmon, and the dog-fish. They stored these oils away in bottles made from the sounds, or air-bladders, of certain fish. They used this oil for a variety of purposes besides food. One of these was the anointing of the bodies of sick persons and also the bodies of twins when wind was desired.

Physical Characteristics.

With the exception of about a score of photographs of men and boys of the Sk·qō′mic I regret to say that I can add no new material to our knowledge of the physical characteristics of this tribe. Dr. Boas's earlier work along these lines among them so prejudiced their minds against anything of the kind that I found it impossible to do anything with them, more particularly after the death of the late Bishop Durieu, who had a great influence over them. The good Bishop had made an appointment with me just before his death sickness, and had promised to exercise his influence in my behalf, and I was sorely disappointed to learn of his death. He told me himself that on the occasion of Dr. Boas's visit many of the Indians ran away and hid themselves in the woods rather than submit to the examinations. I made an effort, however, and chief George 'rounded' me up a score or so of children of all ages, but the mothers of them came upon us before I had measured the first boy's head and dragged them all off. After this I gave up the attempt to do anything with them in this way. I may say, however, that, like the N'tlaka′pamuq, they are clearly a mixed race. We find two distinct facial types among them, one of which is distinctly and markedly Mongolic. I regret being unable to secure a good specimen of this type among my photographs.

Archæology.

Archæological investigation carried on within the territory of the Sk·qō′mic has resulted in revealing to us, among other things, one fact of

special importance. This is that the shores and bays of Burrard Inlet and English Bay have been occupied by rude communities of people for a very considerable period of time. The midden heaps here—the chief monuments of the past in this region—are of two kinds or classes, and clearly belong to two distinct periods. There is the class represented by the refuse heaps seen in the vicinity of every camp site on the coast, and which, generally speaking, are composed almost wholly of the shells of various bivalves, mostly of the clam and mussel kind, and which are clearly of modern or comparatively modern date; and there is the class composed of fewer shells, which are mostly fractured and partially decomposed, numbers of calcined stones and large quantities of ashes and other earthy matter. The latter accumulations bear every characteristic of age, and are undoubtedly of ancient date. I believe these two classes of middens are to be found everywhere on this coast. Wherever I have gone I have always met with them; and Dr. G. M. Dawson has also mentioned them as occurring on the Queen Charlotte Islands in his paper on the Haidas. At all events they are particularly characteristic of this region, and are perhaps the most interesting feature of its archæology. Evidence of an anatomical kind has been secured from the middens of this older class in the neighbouring district of the Fraser, which leads us to believe that a pre-Salishan race once occupied these shores and bays and formed these heaps. Crania, of a type wholly different from those recovered from the burial-grounds of the modern tribes, have been dug up in some of these older heaps. The Sk·qō′mic territory is particularly rich in these evidences of a distant past. On both shores of Burrard Inlet, on English Bay, and around False Creek, the remains of many of these ancient middens are to be found. In some instances they have been partially washed away by the tides, owing to a subsidence in the land since the heaps were formed. In some places the decaying stumps of old cedar and fir trees of immense size are seen embedded in the midden mass. There can be no doubt that many of these stumps are over half a millennium old. They are the remains of what is locally known as the first forest. In numerous instances I have found them and the middens overlying the glacial gravels and clays with no intervening mould or soil between them, while all around in the same vicinity the vegetable mould covers both the gravel and the middens themselves to a depth of from six to twelve inches. Indeed the presence of these old camp sites can often only be discovered by examining the strata of the banks facing the tides.

There is a second reason which leads me to regard these older heaps as præ-Salishan formations. They are not included by the Sk·qō′mic among their old camp sites in the enumeration of their ancient *ō′k·wumūq*, or villages. There is nothing in the Sk·qō′mic traditions which indicates that they were ever occupied by members of the Sk·qō′mic tribe. In my own mind there is no doubt whatever that they are centuries older than the oldest known Sk·qō′mic refuse heaps or camp sites, and were formed by a preceding race. The relics recovered from these ancient middens are not, however, distinguished in any marked manner from those found elsewhere on more modern sites. They represent the usual specimens of bone and stone weapons and utensils, rough and crude specimens being found side by side with finely wrought and polished ones. But if they do not differ in any special manner from known Sk·qō′mic specimens neither do they, for the matter of that, except in the kind of stone

employed, from the remains of ancient peoples elsewhere. Many stone arrow and spear points have been picked up on the beach adjacent to the heaps, from which they have been obviously washed by the action of the tides, which have at some points almost demolished the midden piles. Jade or nephrite adzes, axes, and chisels have also been picked up in the same vicinity; and large numbers of spear and arrow heads 'in the rough' are unearthed from time to time. These latter were apparently hoards or magazines. They can be picked up on the northern shore of Stanley Park at low tide by the score. They are not to be confounded with the waste chips of the arrow maker's workshop so characteristic of some prehistoric camp sites. They are clearly the raw material of the spear and arrow point maker, all showing evidence of having been skilfully broken for the purpose from water-worn boulders of dark basalt. No one could mistake their purpose—their outlines are too obvious. In form, material, and colour they differ radically from the ordinary pebbles and stones of the beach.

As these old middens in the Sk·qō'mic territory resemble in most of their features, except extent and mass, the great middens of the Lower Fraser, I would refer those who desire to learn more of them to my paper on 'Prehistoric Man in British Columbia,' published in the 'Transactions' of the Royal Society of Canada for 1896, in which I have treated of these middens at some length.

Since the Sk·qō'mic have come under the influence of the missionaries they have not only buried their dead in proper graveyards, but have also gathered up and interred in the same place such remains of their dead as could be recovered from their former burial-places. It is difficult, therefore, to secure anatomical material from this region. Some ten or twelve years ago, when the Vancouver City authorities were making the road which now runs round the edge of the penisula which constitutes Stanley Park, they opened one of the larger of the later or Salish middens, utilising the material for the road bed. A considerable number of skeletons was disinterred from the midden mass during the operation, the larger bones and crania of which were gathered up and placed in boxes which were afterwards hidden in the forest where I discovered them a few years later. The crania had then fallen to pieces. A boxful of these bones I shipped later to the Dom. Geol. Survey Museum at Ottawa. From the fact of these bones being found thus inhumated as well as from the recovery of a skeleton in a fair state of preservation in the same heap by myself, it would seem to appear that burial by inhumation sometimes took place in former times even by the Sk·qō'mic themselves, though this was not the prevailing custom when we first came into contact with them. There is, however, no record of burials of this kind in the tribal recollection that I could learn, the traditional method of burial being that already described in my mortuary notes, and it is quite possible these burials in the midden mass were due to the presence of some pestilence or epidemic such as their traditions speak of, and such as we know on good testimony caused the inhumation of a large number of corpses in the Hammond midden on the Fraser a few generations ago. The tribe inhabiting this district was almost decimated by small-pox. So terrible was the scourge that they abandoned their village site after burying all their dead in a big hole. In digging the foundations of his house, the rancher who now owns this spot came upon this pit of bones, and in consequence chose another site for his

dwelling. In the traditional history of the Sk·qō′mic we learn of some terrible sickness which killed off whole villages and caused the abandonment of many *ō′kwumūqs*. The presence of these human remains in the midden in the park may be due to this or some similar cause. No relics, as far as I could learn from the man who had charge of the road making, were found with the bodies; which fact would seem to indicate that they had not been buried in the usual way. I have never discovered or heard of any mounds or tumuli within the territories of the Sk·qō′mic such as are found on the banks of the Lower Fraser and elsewhere. It is extremely doubtful if any such exist among them. Of the old weapons or utensils the stone pestle-hammer is the only one now found among them. I have frequently seen the older men using this tool; indeed they prefer it to our hammers. I once showed some of the younger men some stone arrow and spear points. They did not know what they were or what they had been used for. They had a very ingenious way of keeping their wedges from splitting under the repeated blows of the hammer when splitting cedar boards, &c. They bound the head of the wedge in a most skilful manner with a ring of twisted fibres or split cedar-root which answered the same purpose and almost as effectively as the iron ring on our mallets and chisels. Besides wooden wedges they also used horn ones. Several of their modern tools are fashioned after the pattern of the ancient ones, notably the steel adze they employ in canoe-making and the women's salmon knife. The latter is of the half-moon shape, and generally formed from a piece of a saw, and corresponds in everything but material to the prehistoric slate knives of the middens.

There is a point in canoe-making which the Sk·qō′mic share in common with the other coast tribes of this region to which I cannot recall that any previous writer has drawn attention, but which very aptly illustrates the skill and judgment displayed by our British Columbia Indians in their adaptation of means to ends, and upon which a few remarks will not be out of place here. In shaping the canoe from the solid log the outlines marked out by the builder are very different from those the canoe takes when finished. When looked at from the side just before the steaming process preparatory to spreading the beam has been effected it is seen to have distinctly convex gunwales which rise gradually in the centre six or eight inches above the line of the bow and stern, while the bottom of the canoe is correspondingly concave. The object of this is to insure the gunwales having the proper sweep and curve from bow to stern after the spreading process has taken place, and to prevent the bottom bellying out in the centre, from the same cause. The greater the beam is spread the higher must the gunwales rise at the centre, and the greater must be the concavity of the bottom. In large canoes where the beam is six or seven feet, and the log originally perhaps less than five feet through, to allow of this spread of two feet or so, a very considerable convexity in the gunwales and a proportionate concavity in the bottom of the vessel are necessary. This spreading of the canoe is in itself a very nice task, calling for much judgment and care. It is effected by partially filling it with water and then dropping in heated stones till the water is at boiling heat. On the outside of the canoe, and in close proximity to its sides, fires are also kept up, care being exercised that the sides of the canoe are not burnt in the process. The heat of the fires and the

steaming and soaking give a certain degree of elasticity to the cedar, and prevent the thin sides of the canoe from splitting or cracking under the strain of the spreading. The sides are kept apart and in the proper position by fixed narrow thwarts. The native canoe-builder knows to a nicety just what convexity and concavity to allow respectively to the sides and bottom in every instance, and rarely errs in his calculations. Not every Indian is a canoe-builder of the first order, the art requiring nice judgment and an experienced eye, and our admiration may well be excited by the ingenious method the canoe-builders adopt in overcoming the difficulties imposed upon them by the narrowness of the log. In the hollowing out of the log the canoe-builder again shows his skill and nice judgment. The thickness of the sides and bottom of a canoe is generally under an inch. To the onlooker nothing seems easier than to miscalculate this thickness, and pare off too much or too little in places. Yet the native canoe-builder never does this, but chips out his canoe as uniformly as if it had been turned out of a mould, his only aid being his finger-tips. He *feels* the sides and bottom from time to time as he goes along by the tips of his fingers, placing a hand on each side of his work. By this means he can tell to a nicety the exact thickness of the shell. The Sk·qō′mic have five different canoes, each called by a special term. One at least of these, the Chinook canoe, is a borrowed form. I cannot say if the others originated with themselves. They have of late years added a sixth to their number. This new one is a racing canoe, built on the lines of our four-oared outrigger. I saw one of these at the Mission across Burrard Inlet, the beautiful, graceful lines of which would do no discredit to a first-class yacht-builder. It was hollowed from a cedar log in the usual way, and outrigged like a regular shell, and was altogether a splendid piece of native workmanship.

LINGUISTICS.

The following notes on the languages of the Sk·qō′mic will be the more welcome inasmuch as they constitute the first serious attempt, as far as the writer has been able to learn, to give the peculiarities of the structure of this dialect. While the Sk·qō′mic possesses many of the characteristics common to the Salish tongue, its dialectal differences are so many and great as to mark it off into a distinct class of its own. It shows resemblance to both the Alkōmē′lEm dialects of the Lower Fraser on the one hand and to the dialects of the tribes of the interior on the other, but is quite distinct from any of these, and possesses a grammatical formation, character, and vocabulary wholly its own, which renders it impossible for its speakers to hold extended converse with the neighbouring tribes without the aid of the trade jargon. Though my studies of this tongue have extended more or less over the whole period of my residence in these parts, it is only during the past year that I have given anything like connected thought to the work. Having found an intelligent helper this spring in my studies in the person of a half-breed named Annie Carrasco, I have taken advantage of her assistance to gather a fairly extensive list of phrases and sentences illustrative of the laws and structure of the language. From these and from the story of the SmailEtl, which I have written in the original Sk·qō′mic, a fair knowledge of this dialect may now, with the aid of my notes, be obtained.

My method of working was to supplement the services of Mrs. Carrasco with those of one or more full-blooded Sk·qō′mic. These were generally a woman named Annie Rivers and Chief Thomas of Kuk·aiō′s. My notes, therefore, will, I trust, be free from those errors which sometimes creep into our studies of the native tongues when only the services of half-breeds, with limited and imperfect knowledge of the language, are employed. There are many ways of expressing the same thoughts and ideas in Sk·qō′mic as in other tongues. I have, however, in my grammar notes sought to record at all times the correct or 'classic' forms. Colloquialisms and

'slangey' phrases are quite common, and these are active factors of change in the Sk·qō'mic language as in others. Chief Thomas and others of the older men informed me that the language had changed considerably during the past fifty years, and that every generation of speakers brought in new phrases and expressions, some of which die out and are forgotten, while others are perpetuated and in time become 'classic' or correct forms of speech. It is clear, therefore, that precisely the same laws prevail in the speech of barbarous, unlettered peoples like the Sk·qō'mic as in the language of cultivated and literary stocks.

PHONETICS.

Vowels.

ă	as in	English	h*a*t	*ī*	as in	English	p*i*que
ā	,,	,,	f*a*ther	*o*	,,	,,	p*o*nd
â	,,	,,	*a*ll	*ō*	,,	,,	t*o*ne
e	,,	,,	p*e*n	*u*	,,	,,	b*u*t
ē	,,	,,	th*ey*	*ū*	,,	,,	b*oo*t
E	,,	,,	flow*e*r	*ai*	,,	,,	*ai*sle
i	,,	,,	p*i*n	*au*	,,	,,	c*ow*
				oi	,,	,,	b*oi*l

The vowel sounds in Sk·qō'mic are even more indeterminate than in the N'tlaka'pamuQ. The long vowels are in this respect more at fault than the short ones: *ē* and *ai* final I found particularly troublesome, and at first I was constantly changing from the one to the other, no two Indians uttering them exactly alike. A similar trouble is found in dealing with au and ō. So marked is this characteristic of the Sk·qō'mic vowel that the vocabularies of different collectors would be found to agree but rarely, no matter how carefully they might work.

Consonants.

t as in English. Throughout my studies of the Sk·qō'mic tongue I have been unable to detect the corresponding sonant *d*. Indeed, I am inclined to think that sonants, as distinct from surds, are altogether wanting in Sk·qō'mic. In looking through my collection of terms I find but one single example of g·, and that the harsh form, which at best is only a surd-sonant; no *b* at all and no true *z*, though I have sometimes written this sonant; and in looking over the short vocabulary of the Sk·qō'mic tongue given in the Comparative Vocabulary in the Sixth Report on the N.W. Tribes of Canada, by Dr. Boas, I find that it does not contain a single term with a sonant in it.

k, as in English.

k·, approximately like the final *k* in the word *kick*, uttered forcibly.

g·, rare. In sound it differs little from *k·*.

q, as in the German *ch* in *Bach*.

Q, approximately like our *wh*, but with more force.

H, as in German *ch* in *ich*.

h, y, w, m, n, l, s, as in English; p sometimes as in English, sometimes with a suspicion of the corresponding sonant about it; a quality of sound impossible to render by any written symbol; c as in English *sh*; tc as in English *ch* in the word church; ts, tz, as uttered in English; tl an explosive l approximately like the Welsh ll; sl somewhat as in English, but easily mistaken for tl as uttered by some natives; kl as in English; ç as in English th, as in the word *thin*. In uttering *s* some of the natives show a tendency to convert it into *ts*, these two sounds being practically interchangeable in Sk·qō'mic. The character of the consonants is not nearly so indeterminate as the vowels. The commonest interchanges are:—k·, k; k·, q; q, Q; Q, H; H, h. To mark the hiatus which occurs in certain words I have employed the apostrophic sign; as ts'qāmts = sap

Accent and Tone.

Accentuation is a marked feature of the Sk·qō'mic. Every word that contains more than one syllable has, according to its length, one or more accented syllables. The importance of the accent is seen in such words as have a common form or sound but different meaning. For example, the word sk·ō'mai with the accent on the first

syllable signifies 'hair,' but with the accent on the final syllable, sa sk·umai', it means 'dog.' It seems impossible to lay down any general rule for the position of the accent. In words of two syllables the accent is perhaps oftener placed upon the former than upon the latter syllable; but the exceptions to this usage are so many that it hardly constitutes a rule. Speaking generally, the place of the accent may be said to depend upon the composition of the word. If the word be composed of different radicals having special or independent signification, then the accent will be found on the most important element or radical in the synthesis; as stlEntlānaiō'tl = girls, where the accented syllable signifies 'youth,' the idea to be brought out in the compound. If we want to say 'women' instead of 'girls' this final syllable is wanting, and the accent falls on the second syllable: as stlEntlā'nai. But there are many exceptions to this rule also, for in the compounds sūā-tci'ca = step-mother and sūa-ma'n = step-father we have the accent on 'mother' and 'father' respectively, and not, as by the rule we should expect to find it, on the first syllable *sūa-* = step, as in English. An analysis of the 550 words, more or less, of my vocabulary of the Sk·qō'mic seems to show also that syllables containing a long vowel oftener take the accent than syllables containing a short vowel; but whether this is a mere coincidence or due to the superior importance of the syllable in question I am unable to determine.

TONE.

In monosyllabic terms a tonic accent is at times plainly discernible. It resembles one of the rising tones in Chinese. Father Morice has pointed out the same peculiarity in several of the dialects of the Déné. There, however, the function of tone is the same as in Chinese and marks a difference of meaning in words of the same form and sound; but in Sk·qō'mic this is not so. What purpose this tonic accent subserves in the Sk·qō'mic dialect is not at present clear to me.

NUMBER.

The Sk·qômic contains no true plural: its place is supplied by a distributive formed as in N'tlaka'pamuQ by amplification of the stem, either by reduplication, epenthesis, or diæresis. Reduplication in the Sk·qō'mic is not so strong a feature as in N'tlaka'pamuQ, epenthesis and diæresis occurring oftener. The plurals of both nouns and adjectives are formed in this way; as—

horse	st'kai'ū.	horses	st'ktEkai'ū.
house	lâm.	houses	lElâ'm.
dog	sk·ūmai.	dogs	sk·umkumai'.
mountain	smā'nēt.	mountains	smEmā'nēt.
hill	stcē'tlōs.	hills	stcetltcē'tlōs.
grandparent	sēla.	grandparents	silsē'l.
grandchild	ē'muts,	grandchildren	umē'muts.
old man	stlmōt.	old men	stltlmōt.
youngest (sing.)	saut.	youngest (plur.)	sEsaut.
bad (sing.)	k·ai.	bad (plur.)	k·ai'ak·ai.
beautiful (sing.)	nEtcē'm.	beautiful (plur.)	nEtcnatcē'm.
term of relationship (sing.)	kūē'was.	term of relationship (plur.)	skūikūēwas.
her or him	mEnītl.	them	mEnEnī'tl.

It is observable that the vowel in the reduplicated syllable is invariably shortened if long in the singular form. This is a very constant rule in Sk·qō'mic. We find the verb stem is also sometimes amplified by reduplication, though not in any instance with which I am familiar, for the purpose of expressing number, the reduplicated forms being found in the singular as well as in the plural, thus *sqai'aqai*, to laugh; *tcētcEm*, to swim; *k·ōk·ōt*, to strike; *tlEtlEm*, to rain; *pīpīā'tōtl*, to hunt; *tas-tas*, to do, to make. Here the function of the reduplication is clearly to mark repetition of the action expressed by the verbal stem, and in this respect it agrees with the N'tlaka'pamuQ.

But besides the above functions it has also an augmentative use; thus, *tsō'tlum* = cold, but *tsōtsō'tlum* = very cold; *stā'qais* = a cliff, but *stātā'qais* = a very high cliff. I find that the numerals two and ten undergo modification in certain phrases. For example in the sentence 'I have ten horses,' *ōpEn* = ten is thus modified *ō'ōpEn*;

but in the sentence 'I have ten houses,' the numeral takes the common form *ō'pEN.* It is the same with two = *ā'nōs,* which is amplified in the same way by the reduplication of the initial vowel. I could not learn that this modification took place with other than the word horses, though it is possible my informant's memory may have been at fault. It is quite clear, however, that these modified forms are not commonly used.

INSTRUMENTAL NOUNS.

We find the same suffix *-tEN* employed in the Sk·qō'mic to mark instrumentality as in the N'tlaka'pamuQ, though not always applied to corresponding expressions; thus—

tla'tc-*tEN*, knife, *i.e.*, cutting thing.
pa'tc-*tEN*, needle, *i.e.*, piercing thing.
tlī'tc-*tEN*, saw.
Qē'itc-*tEN*, salmon-knife.
tca'msu-*tEN*, matting needle.
Qok·ō'ls-*tEN*, herb or root basket.
tsē'is-*tEN*, horn.
nukwīyē'utl-*tEN*, ashes.
hu'm-*tEN*, a covering.
sqō'm'-*tEN*, medicine-man.
tlEkqai'ts-*tEN*, platter.
sē'-*tEN*, basket.
nuqyi'm-*tEN*, belt.
n'ku'p-*tEN*, door.
tsētsipē'tl-*tEN*, nest.
k·wē'Ek·-*tEN*, fur.
cūpa'lE-*tEN*, iron.
nūknē'tcim-*tEN*, voice.
tzu'mk·-*tEN*, scissors.
taqu'n-*tEN*, arm.

These terms are very interesting and instructive, throwing much light upon the method of noun formation which is extremely simple in Sk'qō'mic.

AGENT NOUNS.

These nouns are differently formed from the corresponding class in the N'tlaka'-pamuQ, which takes a suffix in *-utl.* Here we find the particle prefixed and quite different in form; as—

nūqskōi'lEc, a shooter,	from kōilac, to shoot
nūqspīpī'atōtl, a hunter,	„ pīa'tōtl or pīpīa'tōtl, to hunt
nūqstEkw'un'p, a digger,	„ tEkwu'n'p, to dig
nūqtzē'tzap, a worker,	„ tzē'tzap, to work
nūqtē'tcEm, a swimmer,	„ tē'tcEm, to swim
nūqsk·ā'tzut, a runner,	„ sk·ātzut, to run
nūqslu'lō, a singer,	„ slu'lō, to sing
nūqsqai'aqai, a laugher,	„ sqai'aqai, to laugh
nūqcā'm, a crier,	„ hām, to cry
nūqsmē'tla, a dancer,	„ mē'tla, to dance

COMPOUND NOUNS.

While there are numerous instances of compound terms in the Sk·qō'mic vocabulary, the composite connotive noun is not a distinguishing feature of the language. An analysis of my collection of words shows that a preponderating number of them are of the simple, denotive class of monosyllabic or dissyllabic form. Incorporation or polysyntheticism scarcely finds a place in Sk·qō'mic, the compound forms partaking rather of the character of the Greek and Latin compound terms in English than the ponderous syntheses of the Déné and Algonkin. The new compound term employed by the Sk·qō'mic to express the idea of a garden is a fair example of the formation of their composite terms. Formerly they had no gardens of their own, and so had to coin a word when they took up horticulture. This term is *nE-pEN-ma'i,* which is formed by the juxtaposition of these independent monosyllabic radicals which signify respectively 'where' 'get,' 'fruit' or 'vegetables,' and the whole thus means 'the place where one gets fruit or vegetables.'

Other examples may be seen in the terms employed to express the seasons of the year, where we have the same simple juxtaposition of independent radicals. The analysis of the composite terms in Sk·qō'mic is, therefore, relatively an easy task. For example, the word *sēntlqōyatc,* meaning 'thumb,' is thus resolved: sēntl = first or oldest; qō = finger; yatc = the composite form for 'hand.' This last element is necessary in the synthesis to distinguish the word from 'big-toe,' which would be thus written, *sēntl-qō-cin,* cin signifying 'foot.' And so with the word for 'little finger,' *saut-qō-yatc,* where saut = 'youngest' or 'last.' Again, the word expressive of the

noise made by people talking, which is *snā'-nsut*, is thus resolved into two independent radicals: *snā'* = 'name' or 'word,' and *nsut* = 'noise' or 'sound.' Compare with this the word *tcē'ansut*, which means 'noise' as made by children playing together. Numerous other examples may be found in the vocabulary.

Gender.

Grammatical gender is not entirely wanting in the Sk·qō'mic as amongst the N'tlaka'pamuQ. The article and the personal pronoun of the third person singular (which, strictly speaking, is rather a demonstrative than a true pronoun) and the possessive pronoun of the first person singular have distinct masculine and feminine forms. Thus *tE*, 'a' or 'the' (masc.), *tlE*, 'a' or 'the' (fem.); *tai* or *tē*, 'he;' *ā'tli*, 'she;' *tEn*, 'my' (masc.); *tlEn*, 'my' (fem.). These possessives, monosyllabic though they be, are compound forms derived from the articles *TE* and *tlE* and *n*, the characteristic element of the first personal pronoun. It is the same *'n* or *EN* = 'my,' as we find in N'tlaka'pamuQ, and which appears so constantly in the irregular verbal forms of the first person singular in all our Salish dialects. The usage of these pronouns is interesting. The function of gender is peculiar. As gender is wanting to the Sk·qō'mic substantive, there can be no agreement between the possessive and the thing possessed, as in the classic tongues. The gender of the pronoun in any given sentence depends entirely upon the sex of the speaker. A woman must always say *tlEn*, and a man *tEn*. Thus, *tlEn* lām, 'my house,' by the woman, and *tEn* lām by the man. This is the general usage of the two forms. Even in such instances as when the speaker uses terms which are applied exclusively to males or females, such as 'husband,' 'wife,' 'father,' 'mother,' 'brother,' 'sister,' &c., where the distinct form gives a kind of gender to the word, the possessive does not agree in gender with the substantive, as might, on the analogy of classic usage, be expected. It would be impossible for a man to say '*tlEn* tcūwa'c,' 'my wife,' or a woman to say '*tEn* skō',' 'my husband;' the combination would be ridiculous. There is, however, an interesting exception to this general rule. Whenever a general term expressive alike of 'male' and 'female' is employed, then both men and women place *tlEn* before the word when they are speaking of a female, and *tEn* when they are referring to a male, thus: *tlEn mEn*, 'my daughter,' and *tEn mEn*, 'my son,' the function of the possessive here being to give the gender to the noun.

The function of the article is quite different from that of the pronoun, the form employed in any given expression depending in no way upon the sex of the speaker. It conforms rather to classic usage, and its gender is 'governed' by the gender of the noun it is qualifying. But, as I have already stated, as there is no grammatical gender of the noun in Sk·qō'mic, the division into masculine and feminine terms is rather a mental than a formal process. Of neuter forms there are none, the distinction being impossible to the Indian mind. In his conception every object in nature, animate and inanimate, is a sentient being, possessing a character and individuality of its own, and has therefore male or female attributes. The Sk·qō'mic child learns to distinguish in his mind masculine 'ideas' from feminine ones just in the same unconscious way as he learns his mother's tongue, and in ordinary discourse has no more trouble over his article than a French child has over his. Indeed, in the matter of concord the use of the article in the Sk·qō'mic and French closely agrees, but in Sk·qō'mic the article has usages peculiar to the language, being used in a variety of ways unfamiliar to us in the French. For example we find it in such sentences as the following: 'nētl tE Harry,' 'it is Harry;' 'nētl tlE Mary,' 'it is Mary.' It is also employed with the personal pronouns in certain expressions where it seems to have a prepositional force, thus: 'hauq mēkauq haua *tlE* uns?' (or *tE* uns, according as the 'me' is male or female), 'Will you not come *with* me?' and also with the personal and possessive pronouns generally (see under 'Pronouns'). It is also invariably placed before proper and tribal names, closely resembling in this respect in form and function the usage of the article in Polynesian. Besides these grammatical distinctions of pronominal and demonstrative gender we find the ordinary distinctions of separate words to denote male and female objects, thus:—

suē'ka, man;	stlā'nai, woman;
suēkao'tl, boy;	stlānaiō'tl, girl;
suē'wolō's, youth;	k·ā'mai, maiden;
mama, father;	tci'ca, mother;
sē'saē, uncle;	ţzā'ata, aunt.

In animal terms I could not find this distinction. When speaking of animals, if it is necessary to distinguish sex, it is done by placing modified forms of the terms for 'man' and 'woman' before or after the class word, thus:—

suēawē'ka sk·umai', dog	stla'tlenai sk·umai', bitch.
sQēcen suēawē'ka, deer	sQēcen stla'tlenai, doe.

In this respect the Sk·qō'mic agrees closely with the N'tlaka'pamuQ. In both dialects it is observable that the modification of the qualifying word, though an amplification of it, differs from that which marks the plural. The reason of the reduplication here is not clear. There are a few terms used of male and female alike without distinction of form in the use of which, if there is a possibility of ambiguity, the pronominal forms *tai* and *ā'tli* are added, thus:—

stāō'tl, child.	wā'nim, orphan.
sīā'atEn, widow (ā'tli).	sī'yā, lover.
„ widower (tai).	

CASE.

The Sk·qō'mic noun agrees here with the N'tlaka'pamuQ, and ordinarily undergoes no modification for case. In certain expressions modified forms of the inflectional personal pronouns are added to a word to mark possession or ownership, as in the N'tlaka'pamuQ, thus:—

tEn, tlEn, or 'n-lām, my house; lām-tcit, our house;
tE-lām or E-lām, thy house; lām-yap, your house;
(tE) lām-s, his house; (tE) lām-s-wēt, their house.

There is a very close resemblance here to the N'tlaka'pamuQ, though some of the pronominal elements differ and the 'present' and 'absent' forms of the pronoun are wanting in the Sk·qō'mic.

The object noun when not the name of a part of the body is invariably distinct from the verb, and undergoes no modification whatever, and commonly follows the verb as in English, thus:—

nE-qōī'-nūq-ūās tEn sk·umai', 'he killed my dog;'
nō'wēt yū'itl, 'they are making a fire;'
mē'ska tEn yā'sīauk·, 'give me my hat;'
nE-hōi-nūq-ūās tEn lām, 'he has completed my house.'

When, however, the object affected by the verbal action is a personal pronoun other than the third persons, or is a noun descriptive of a part of the speaker's body, then the object suffers modification, and is incorporated in the verbal synthesis. But this incorporation is of a much looser character than in the typical incorporative tongues or even in the kindred dialect of the N'tlaka'pamuQ. In the latter the incorporated object, both noun and pronoun, is placed between the stem of the verb and the personal inflection. In Sk·qō'mic the verb stem and subject pronoun are always found together, and the object, whether noun or pronoun, is added to these terminally as a suffix, thus:—

NOUN OBJECT.

tcin-sā'k·- *aiyan*,	I hurt my ear;			tcin-sā'k·*cEn*,	I hurt my foot		
tcin-sā'k·-*ōs*,	„	„	face	tcin-sā'k·-*hātlka*	„	„	neck (side)
tcin-sā'k·*qatc*	„	„	hand	tcin-sā'k·-*hēnEs*	„	„	chest
tcin-sā'k·*āks*	„	„	nose	tcin-sā'k·-*sai*	„	„	elbow
tcin-sā'k·-*atcō*	„	„	forehead	tcin-sā'k·-*uk*	„	„	head
tcin-sā'k·-*āts*	„	„	mouth	tcin-sā'k·-*qō-yatc*	„	„	finger
tcin-sā'k·*āk·En*	„	„	arm				

PRONOUN OBJECT.

tcin-tlē-*stō'mi*, I love thee.
tcin-tlē-*sē'wit*, I love you.
'n-tlēs tai or tE mEnī'tl, I love him.
'n-tlēs ā'tlī or ā'tli mEnī'tl, I love her.
'n-tlēs ītsi mEnEnī'tl, I love them.
tcit-tlē-*stō'mi*, we love thee.
tcit-tlē-*sē'wit*, we love you.
tcit-tlē's-*wēt*, we love them.
tcit-tlēs tai or tE mEnī'tl, we love him.
tcit-tlēs ā'tli or ā'tli mEnī'tl, we love her.
(nE-)tlē-*stsā's*, he loves me.
tcūq-tlē's-tum, he loves thee.

tcap-ūă-tlē's-tum, he loves you.
(nE-)ē'uq-tlēs, he loves them all.
(nE-)tlē'*sēs* (tai), he loves him.
tcūq-tlē'-*sts*, thou lovest me.
tcūq-tlē-*stō'mutl*, thou lovest us.
tcap-tlē-*sts*, you love me
tcap-tlē-*stōmutl*, you love us.
tlē-*sts-as*-ē'tsī-wēt, they love me.
tca'p-ūă-tlē'stum, they love you.

The Sk·qōmic, in common with most of our native tongues, is rich in synonyms and synonymous expressions. Nearly every one of the above pronominal expressions can be otherwise rendered. I append a few of these :--

'n-tlēs-tcap, I love you ; or, again, tcin-tletcap, I love you ;
wūt-tlēsās, he loves me ; tcūq-ūă-tlē stum tE ētsi-wēt, they love thee
tlē-stō'mi-tcan-wit, I love you ; tlēs-tcan-wēt, I love thee.
tum-tlē-ētsi-tlE-nēmutl, they love us.

It will be observed that when the object is in the third person no incorporation takes place. This is the same as in the N'tlaka'pamuQ and other dialects. This is due to the fact that the personal pronouns for this person are yet scarcely differentiated from the demonstratives from which they are derived. This is plainly seen in the absence of a distinct and independent subject pronoun for the third person in the pronominal inflections of the verbs. The Salish dialects are just at that stage of development when the formation of distinct pronominal forms for the third person takes place. The N'tlaka'pamuQ has a partially developed subject-pronoun for its transitive verbs, and is thus a stage in advance of the Sk·qō'mic, but neither has distinct forms for the third person for the *verbum substantivum* or for intransitive verbs.

It will be seen in the above incorporative nouns that the synthetic forms differ less from the independent forms in the Sk·qō'mic than in N'tlaka'pamuQ, and this holds good of all the nouns. A few are derived from different roots, which it is interesting to note are often those which belong to independent forms in others of the Salish dialects. The Sk·qō'mic incorporative noun is generally an attenuated form of the independent noun. It is interesting to note that in the 'face' synthesis we have the root as it appears in the N'tlaka'pamuQ compound. It is only in compounds that this radical appears in Sk·qō'mic, and the same may be said of many others. As I observed in my remarks on N'tlaka'pamuQ, this preference for one synonymous form over another in the various divisions is one of the chief causes of the lexicographical dissimilarity in the Salish dialects. If we compare, for example, the words for 'house' in Sk·qō'mic and N'tlaka'pamuQ, we find the vocabulary form in the former is *lăm*, and in the latter *tcī'tūQ*, of which the essential root is *tūQ*. I cannot say if *lăm* appears in any form in N'tlaka'pamuQ, but *tūQ* certainly does in various compounds in Sk·qō'mic, thus making it perfectly clear that this is one of the primitive Salish roots expressive of 'house.' Thus, we have it as the suffix in the class numerals when counting houses: *samp-tūQ*, 'two houses'; *tcanau*-tūQ, 'three houses,' &c.; also in the compound signifying 'potlatch-house,' tlā'anukau*tū'Q*. Again, a house with carving in or upon it is called stcu'*tūQ*. It is seen also in the compound for window and other words. I have dwelt upon this point rather because it confirms my contention that the only way to institute comparisons in American tongues is by the resolution of compound terms into their constituent primitive radicals. Till this is done we can never know what tongues are really related and what are not.

PRONOUNS.

The independent personal pronouns are:

uns, I ;
tE nō, thou.
tai, he.
ā'tli, she.
nē'mutl, we.
nū'yāp, you.
tsi or ē'-tsi, they.

All of these may be used objectively as well as subjectively. There is another form for the third persons. I have found it only as an objective, thus :—

TE menī'tl, he ; ā'tli mEnī'tl, she ; ētsi mEnEnī'tl, them. Besides these there is an 'absent' form, thus :—

Kūą̄, he ; Q'tlā, she. These latter forms appear in such sentences as the following ; *Q'tlă nūa Esk·q'i na tE Qōau'tūQ.* 'She is ill at the hospital, or sick-house.' This

is not a common form, and the regular method of marking the absence of the third person is by prefixing the particle *nE* (see below).

Possessive Pronouns.

Singular	tE-n (masc.), tie-n (fem.), my.		Plural	tE . . . -tcit, our.
	tE,	thy.		tE . . . -yāp, your.
	tE . . . -s,	his or hers.		tE . . . -swēt, their.

The distinction in the possessive, marking the absence or presence of the object seen in N'tlaka'pamuQ, is wanting in the Sk·qō'mic. In the latter dialect there is but the one common form, but it possesses a masculine and a feminine for the first person singular, which is unknown in N'tlaka'pamuQ. The function of this gender I have already dealt with on p. 499. Besides tEn and tlEn we find for this person two other forms used alike by males and females. These are *sEn* and *kōEn*. According to my informants they can be used almost in any expression in the place of the regular tEn and tlEn forms. I found them in such expressions as *nE-qōi-nuq-ūās sEn sk·umai'*, 'he killed my dog;' *kōEn mEnmEn*, 'my sons.'

In conjunction with the *verbum substantivum* and a demonstrative, they are thus expressed:—

nētl 'n lāmti,	this is my house;	nētl sō'otl lām ti,	this is our house.
„ u-lām ti,	„ thy „	„ ti lām-yāp,	this is your house.
„ lām-s ti,	„ his „	„ „ lām s-wēt,	this is their house.

Substantive Possessive Pronouns.

These forms are used in answer to such questions as 'Whose is this?'

nētl 'n-swā,	it is mine;	nētl sō'otl,	it is ours.
„ u-swā,	„ thine;	„ u-swāyap,	„ yours.
„ swa-s (tai)	„ his;	„ swa-s-wēt,	„ theirs.
„ swa-s (ā'tli)	„ hers;		

Inflectional Subjective Pronouns.

Singular	tcin-, I.	Plural	tcit-, we.
	tcūq-, tauq-, auq-, thou.		tcap-, you.
	— he, she (present).		wēt, ētsi, they (present).
	nE „ (absent).		nEwēt, „ (absent).

In the perfect and future tenses and in certain other constructions the tcin and tcit of the first person singular and plural undergo a modification and change to tc*a*n and tc*a*t respectively.

There are modifications of all the pronominal forms in the conditional, dubitative, desiderative, and other moods of the verb. For these irregular forms see under 'Verbs.'

Construction of Pronouns with Verbs.

The transitive verb forms are not in Sk·qō'mic distinct from the intransitive and *verbum substantivum* forms as in N'tlaka'pamuQ. The only difference between the two forms is in the third person, which takes the characteristic terminal *-s* or *-Es* in both numbers, and this only in the past and future tenses, thus: nE-k·ō'k·ōt-*Es*, he struck (it); nE-k·ō'k·ōt-*Es-wē't*, they struck (it).

It will be observed that the pronoun in Sk·qō'mic precedes the verb in regular constructions; in N'tlaka'pamuQ it follows it. In certain constructions the pronoun is placed after the verb in Sk·qō'mic. When so placed a different sense is given to the expression, thus: 'Nâm-tcin tla town' means 'I am going to town,' but 'tcin-nâm tla town' means, on the contrary, 'I have been to town,' or, I am going back from town.' Again, in answering a question, it is usually suffixed; thus in answer to the question, 'ōtcuq Esk·ōi?' 'are you sick?' the answer would be *ū'ā-tcan Esk·ōi*, or shortly *ū'ā-tcan*. In such instances the vowel is always changed to *a*. This applies equally to the plural form.

Interrogative Pronoun.

(Singular) Sūāt? who? { sūāt kūē nE-tas ti? who made or did that? / sūāt ti? or sūāt kūē'tsi? who is that?

(Plural) Sōwat? who? sōwat kūē'tsi? who are those?
stām? what? Stām k·ūē'-ūā-qōistauq? what are you eating?
which? u'ntca? nEtl u'ntca kōēē' lām? which is your house?

Reflexive Pronouns.

nōmōt,	self.
tcin-k·ōk·*nōmōt*,	I struck myself.
nE-k·ōk·-*nōmōt*,	he „ himself.
tcit-k·ōk·-*nōmōt*,	we „ ourselves.

Demonstrative Pronouns.

tE (masc.), the.	tlE (fem.), the.
ti, this, that.	tsi or ē'tsi, these, those.

In Sk·qō'mic there is no difference between 'this' and 'that,' these' and 'those,' as in N'tlaka'pamuQ.

hātl ti lām, that or this house is good.
ti ūā lām hātl, this or that is a good house.
hahā'tl ē'tsi sīwē'Eka, these or those men are good.

Dr. Boas has recorded the form *nītl* as 'this,' nītl or nētl, as I write it, is a compound term, and signifies 'it is' or 'this is,' or 'that is,' nē being a form of the *verbum substantivum*. He has also recorded in his short vocabulary of the Sk·qō'mic in the Sixth Report on the North-Western Tribes of Canada, 1890, masculine and feminine forms for 'that,' *tō'nītl* (masc.), *çō'nītl* (fem.). I have been unable to discover these myself in the Sk·qō'mic.

NUMERALS.

Cardinals.

Of these there are several classes as in N'tlaka'pamuQ, but they are differently formed. The common cardinal numbers are:—

1. 'ntcō
2. ā'nōs
3. tcā'nit
4. qau'EtsEn
5. tsē'atcis
6. t'ā'qatc
7. t'ā'qōsatc
8. t'qatc
9. tssEs
10. ō'pEn
11. ō'pEn īkwī 'ntcō
12. „ „ ā'nōs

The 'teens' follow regularly.

20. Qōtltc
21. „ īkwī 'ntcō

The others follow regularly.

30. sau'quaca, tlō'qca
40. qau'EtsEnca
50. suk·tca'ca, tlu'k·ca
60. taqmu'tlca
70. tsukō'lca
80. t'ku'tcica
90. tssāw'itc
100. natcāwitc

Ordinals.

With the exception of 'first' and 'last' the ordinals do not in Sk·qō'mic differ in form from the cardinals. For 'first' they say *yāwu'n*, and for 'last' they use the term *āaut* or *aut*.

Class Numerals.

The following forms are employed when counting houses though not exclusively so; and it would appear that the younger people use the independent forms as often as the composite.

1 house	nā'tcatuQ.
2 houses	sāmptuQ (a shortened form of sāmpautuQ).
3 „	tcanautuQ.
4 „	qauEtsenautuQ.

For counting trees they use the following :—

1 tree 'ntcē'wā.
2 trees ānōsē'wā.
3 ,, tcanEtē'wā.

When counting canoes the following may be employed:—

1 canoe natcākōītl.
2 canoes Sāmākōītl.
3 ,, tcanākōītl.

It will be observed that the method of forming the class numerals in the Sk·qō'mic differs considerably from that employed in N'tlaka'pamuQ. I find no instance of reduplication of the stem.

It will also be observed that 'two,' &c., is sometimes expressed by ā'nōs and sometimes by sāmā' or tsāmā'. The former of these terms is peculiar to the Sk·qō'mic and their northern neighbours the StlatlumH, according to Dr. Boas's Salish Comparative Vocabulary. The latter is found in the SEQua'pmuQ of the interior, and also among the Coast Salish. I could find no trace of either in N'tlaka'pamuQ, where *cai'a* is uniformly employed to express 'two' &c.

Numeral Adverbs.

These are not so regularly formed as in the N'tlaka'pamuQ, though we find the same characteristic suffix '*-atl*' in both, thus:—

once	natcauq.	9 times	tssEsa'tl.
twice	tsāmā'.	10 ,,	ō'pEnatl.
thrice	tcEnauq.	11 ,,	slama'tl.
4 times	qauEtsna'tl.	12 ,,	ā'nōs tEslEms.
5 ,,	tsī'ētca'tl.	13 ,,	tcanit tE slEms.
6 ,,	t'ā'qatca'tl.	14 ,,	qauEtsEn tE slEms.
7 ,,	t'ā'qōsa'tcatl.	20 ,,	Qōtltcatl.
8 ,,	t'qa'tcatl.		

'Eleven' appears under a strange form here.

ADJECTIVES.

The regular position of the adjective is *before* the word it qualifies, thus: *tōlau* tE tlk·aitc, 'bright the moon;' hāhā'tl ē'tsi sīwē'Eka 'good are those men,' hāhā'tl sīwē'Eka ē'tse, good are these men. In such phrases as 'this house is good' and 'this is a good house,' they mark the difference thus: hātl tī ūā lām = 'this house is good;' tī ūā lām hātl = 'this is a good house.'

The adjective invariably agrees in number with the qualified word, as in the examples above. Comparison of the adjective is effected in the following manner:—

Positive	Comparative		Superlative
hātl, good	yāwo'n hātl, or āsa'tc hātl,	more good	nāo'n hatl, best

The superlative is also expressed by tone, the speaker drawing out the positive forms on a rising note much as little children do with us in English.

Of the two forms in the comparative the former is clearly the same term as 'first' in the ordinals; the latter is a preposition signifying 'above,' 'over,' &c.

ADVERBS.

The function and position of the adverb are much the same as in N'tlaka'pamuQ. When t expresse 'time' it is invariably placed before the verb, thus:—

Tcī'atl ī'mē tcē'Ek tE tlk·aitc, 'the moon will rise soon;' *tcī'atl* tcin-ī-nâm, 'I must go soon;' *natcauq* kūisE's mē tEn lām, 'he came to my house once;' *tlē'Ek·t* tcin-t-ū'ā-nâm, 'often I used to go.'

VERBS.

The inflexion of the verb in Sk·qō′mic is effected partly by affixing particles and partly by auxiliary verbs. These, in such sentences as we form in English with the *verbum substantivum* and a noun or adjective, are: present tense, *ū′ā*; past indefinite, *t-ū′ā*; perfect, *t-ī-ūā*; future, *Ek·*.

VERBUM SUBSTANTIVUM.

The Sk·qō′mic employ the regular verb of being characteristic of the Salish dialects, the simplest and most constant form of which is *ū′ā* (see below under the verbal inflections); but besides this regular form we find three others, *ē*, *nē* or *nētl*, and *i-* (this latter is also seen in the Kwakiutl). Thus: *ē-tcin-Esk·ō′i*, 'I am sick;' *ē-Esk·ō′i*, 'he is sick;' *nētl tE Harry*, 'it is Harry;' *nētl 'n lām ti*, 'this is my house'; *ens-i*, 'it is I,' in answer to question 'Who is that?' *ens-i nE tās*, or simply *ens-i*, 'I did,' or more literally, 'it is I,' in answer to question 'Who did it?

INTRANSITIVE VERBS.

sick = *Esk·ō′i*, or sk·ō′i.

Present Tense.

Singular:
- ē-tcin-ūā-Esk·ō′i, I am sick.
- ē-tcūq-ūā-Esk·ō′i, thou art sick.
- ē-ūā-Esk·ō′i (tai), he is sick (present).
- ē-ūā-Esk·ō′i (ā′tli), she is sick (present).
- nE-ē-ūā-Esk·ō′i, he is sick (absent).

Plural:
- ē-tcit-ūā-Esk·ō′i, or sk·ūēk·ō′i, we are sick.
- ē-tcap-ūā-Esk·ō′i, or sk·ūēk·ō′i, you are sick.
- ē-wēt-ūā-Esk·ō′i, or sk·ūēk·ō′i, they are sick (present).
- nE-wēt-ūā-Esk-ō′i, or sk·ūēk·ō′i, they are sick (absent).
- or nE-ē-wēt-ūā-Esk·ō′i, or sk·ūēk·ō′i, they are sick (absent).

In ordinary speech the adjective or noun is not usually reduplicated for the plural. In formal speech, however, the plural forms must never be omitted.

These forms may be called the regular or classic forms. It is quite common, however, in ordinary speech to omit one or other or both of the auxiliary verbs *ē* and *ū′ā*, placing the pronoun and adjective in simple juxtaposition, thus: tcin-Esk·ō′i, tcūq-Esk·ō′i, &c.

In the third person of both numbers the form nō′a or nau′a is quite commonly used, thus: nō′a Esk·ō′i, 'he or she is sick;' nō′a yē′yEk·, 'it is snowing;' nō′a sātsauq-wēt, 'they are happy' (see other examples below).

Past Indefinite Tense. I.

Singular:
- ē-tcin-t-ūā-Esk·ō′i, I was sick.
- ē-tcūq-t-ūā-Esk·ō′i, thou wast sick.
- ē-t-ūā-Esk·ō′i (tai), he was sick (present).
- ē-t-ūā-Esk·ō′i (ā′tli), she was sick (present).
- nE-ē-t-ūā-Esk·ō′i (tai), he was sick (absent).
- nE-ē-t-ūā-Esk·ō′i (ā′tli), she was sick (absent).

Plural:
- ē-tcit-t-ūā-Esk·ō′i, or sk·wēk·ō′i, we were sick.
- ē-tcap-t-ūā-Esk·ō′i, or sk·wēk·ō′i, you were sick.
- ē-t-wēt-ūā-Esk·ō′i, or sk·wēk·ō′i, they were sick (present).
- nE-wēt-t-ūā-Esk·ōi, or sk·wēk·ō′i, they were sick (absent).

Past Indefinite Tense. II.

nE-tcin-t-ūā-Eskō′i, I was sick, nE-tcit-t-ūā-Esk·ō′i, we were sick.

The other persons follow regularly.

The difference between these two tenses is that the former merely makes a statement of a past sickness without implying anything of the present condition of the patient, while the latter signifies that the person was sick but has since recovered, and is now well.

Perfect Tense.

Singular
ē-tcin-t-ī-ūā Esk·ō′i, I have been sick.
ē-tcūq-t-ī-ūā Esk·ō′i, thou hast been sick.
ē-t-ī-ūā Esk·ō′i (tai), he has been sick.
ē-t-ī-ūā Esk·ō′i ′ā′tli), she has been sick.

Plural
ē-tcit-t-ī-ūā Esk·ō′i, or sk·ūēk·ō′i, we have been sick.
ē-tcap-t-ī-ūā Esk·ō′i, or sk·ūēk·ō′i, you have been sick.
ē-t-wēt-ī-ūā Esk·ō′i, or sk·ūēk·ō′i, they have been sick.

It is not clear to me wherein this form differs in signification from the ′tūā forms. It is the regular perfect of transitive verbs.

Future Tense.

Esk·ō′i-tcan-Ek·, or tcan-Ek·-Esk·ō′i, I shall be sick.
Esk·ō′i-tcat-Ek·, or tcat-Ek·-Esk·ō′i, we shall be sick.
The other persons follow regularly in like manner.

Periphrastic Future.

ens-ko′lūān Esk·ō′i-En-Ek·, I think I am going to be sick.
tcin-ēpā′Qotl Esk·ō′i-En-Ek·, I am afraid I shall be sick.

Dubitative Forms.

ēwai′Eti Ek· ′sk·ō′i-En, I may or perhaps I may be sick.
„ „ ′sk·ō′i-auq, thou mayest be sick, &c.
„ „ ′sk·ō′i-Es, he may be sick, &c.
„ „ ′sk·ō′i-at, we may be sick.
„ „ ′sk·ō′i-ap, you may be sick, &c.
„ „ ′sk·ō′i-Es-wēt, they may be sick, &c.

Conditional Forms.

HEn-ūā-Esk·ō′i, if I am or should be sick.
Hat-ūā-Esk·ō′i, or sk·ūēk·ō′i, if we are or should be sick.
KūEns ē-ūā-Esk·ō′i, when I am sick.
KūEs ē-ūā-Esk·ō′i, when thou art sick.

Interrogative Forms and Replies.

ō-tcūq-Esk·ō′i? are you sick? (singular).
tcan-ūān-Esk·ō′i, or simply tcan-ūān, I am.
ō-tcūq-t-ūā-Esk·ō′i? have you been sick?
tcan-t-ūā-Esk·ō′i, or simply nE-tcan, I have.

Negative Forms.

hauq Enslē′as kūEns Esk·ō′i, I don't want to be sick.
hauq Enslē′as kūEns nâm, I don't want to go.
hauq ōq-nâm, don't go.
hauq ōq-nam skō tai, don't go with him.

Miscellaneous Forms.

nētl ens-nâm, I am going (in answer to question 'are you going?' it would be nâm-tcan).
haua mEn nâm-tcan, I shall (determination) go.
nâm tcan Ek·, I shall go (future).
nâmEtl, go on.
nâm tumī′, go away.
tcin-t-nâm, I went.
nE-t-nâm, he went.
tcan-tQ-nâm, or tcan-tH-nam, I have gone.

tcan-tēkH-nâm, I had gone.
ēwai'Eti Ek· nâm-En, perhaps I shall go.
'n slē kūEns nâm, I should like to go.
nâm-tcin haua tla nō, I will go with you.
hauōk· mēauq haua tla uns, will you not come with me ?
nE-tsōt kūEs nâms-ē'uk, he said he was going with me.
tcin-tsōt kūEns nâm-ē'uk, I said I was going.
nE-tsōt kūEns k·aiE suē'Eka, he said I was a bad man.
nE-tsōt kauq mEn nâm, he said you (sing.) ought to go.

TRANSITIVE VERBS.

The principal tense signs of the transitive verb are: past indefinite, *nE*; perfect, ī; future, Ek·.

Transitive Verb.

to strike (it) k·ō'k·ōtEs.

Singular:
tcin-k·ō'k·ōt, I strike (it).
tcūq-k·ō'k·ōt, thou strikest (it).
(tai)k·ō'k·ōt, he strikes (it)
(ā'tli) k·ō'k·ōt, she „ „

Plural:
tcit-k·ō'k·ōt, we strike (it).
tcap-k·ō'k·ōt, you „ „
k·ō'k·ot-ē'tsi, they „ „

This tense is quite frequently employed to express a past action, the context marking the time quite clearly.

Past Indefinite Tense.

Singular:
nE tcan-k·ō'k·ōt, I struck (it).
nE tcūq-k·ō'k·ōt, thou struck (it).
nE k·ō'k·ōtEs, he (present) struck (it).
nE k·ōk·Enūqūās, he (absent) struck (it).

Plural:
nE tcat-k·ō'k·ōt, we struck (it).
nE tcap-k·ō'k·ōt, you struck (it).
nE k·ō'k·ōtEswēt, they (present) struck (it).
nE k·ōk·Enūqūāswēt, they (absent) struck (it).

Perfect Tense.

tcan-ī-k·ō'k·ōt, I have struck (it).
tcat-ī-k·ō'k·ōt, we have struck (it).

The other persons follow regularly.

Future Tense.

Singular:
k·ō'k·ōt-tcan-Ek·, I shall strike (it).
k·ō'k·ōt-tcūq-Ek·, thou wilt strike (it).
Ek·-k·ō'k·ōtEs, he will strike (it).

Plural:
k·ō'k·ōt-tcat-Ek·, we shall strike (it).
k·ō'k·ōt-tcap-Ek·, you will strike (it).
k·ō'k·ōtEs-wēt-Ek·, they will strike (it).

Imperative Mood.

k·ōk·ō'tka, strike it (singular) k·ōk·ōtka'wit, strike it (plural).
mEn-k·ō'k·ōt-tcan-Ek·, I must strike (it).
mÉn-k·ōkō'tka, you must strike (it).
mEn-k·ō'k·ōt-tcat-Ek, we must strike (it).
kōk·ōtska, strike me. k·ōk·ōt-tōmEtlka, strike us.

Present Continuous Action.

ē-tcin-ūā-k·ōk·ōt, I am striking (it).
ē-tcūq-ūā-k·ōk·ōt, thou art striking (it).
ē-ūā-k·ōk·ōt, he (present) is striking (it).
nō'a-k·ōk·ōtEs, he „ „ „
nE-ūā-k·ōk·ōt, he (absent) „ „

The plural follows regularly.

Past Continuous Action

tcan-t-ūā-k·ō′k·ōt, I was striking (it).
tcat-t-ūā-k·ō′k·ōt, we were striking (it),

The other persons follow regularly.

Perfect Continuous Action.

nE-tcan-t-ūā-k·ōk·ōt, I have been striking (it.)
nE-tcat-t-ūā-k·ōk·ōt, we have been striking (it).

The other persons follow regularly.

Negative Forms.

hauq Hunk·ōk·ōt, I did not strike (it).
hau-Ek· Hunk·ōk·ōt, I will not strike (it).
hau-it Hat-k·ōk·ōt, we did not strike (it).
hauq auq-k·ōk·ōt, don't strike (it).
hauq auq-k·ōk·ōts (ens), don't strike me.

Passive Forms.

tcin-k·ō′k·, I am struck. tcit-k·ō′k·, we are struck.

The other persons follow regularly.

ēwai′Eti Ek· k·ōk·-ūān, I may be struck.
,, ,, k·ōk·-ūāt, we may be struck.

The other persons follow regularly.

tcin-t-k·ōk·, I have been struck. tcit-t-k·ōk·, we have been struck.

The other persons follow regularly.

k·ōk·-nōmōt-tcan-Ek·, I shall be struck.
k·ōk·-nōmọ̄t-tcat-Ek·, we shall be struck.

The other persons follow regularly.

Conditional Action.

Hun-k·ōk·ōt, if I strike (it). Hat-k·ōk·ōt, if we strike (it).
k·auq-k·ōk·ōt, if you strike (it). Hun-k·ōk·ō′tEm, if I am struck.

Reflexive Forms.

tcin-k·ōk·-nō′mōt, I struck myself. tcit-k·ōk-nō′mōt, we struck ourselves.
The other persons follow regularly.
k·ōk·-nō′mōt-tcauq-Ek·, you will strike yourself.

Additional Forms.

mEn-k·ōk·ōt-tcan-Ek·, I must strike (it).
Hātl kūEs ēuq tcat-k·ōk·ōt, let us all strike (it).
nēmutl-ka-k·ōk·ōt, let us strike (it).
uns-ka-k·ōk·ōt, let me strike (it).
nE-k·ōk·-ōtsis, he struck me with a stick (purposely).
nE-k·ōk·-numcis, he struck me with a stick (accidentally).
k·ō′k·ōt-ō-tcin? can I strike it?
ēwai′Eti Ek· k·ōk·ō′t-En, I may strike it.

To bring out further the grammatical structure and peculiarities of the Sk·qō′mic I append a list of general expressions:—

Enslē-ī kwē stauq, I should like some water.
En-slē-ī kwē ē′tlen, I should like some food.
Eṇ-slē kūẹEns pEnaqūān kwẹ st′kai′ụ, I should like to have a horse,

tcin-kōas-nūq, I burnt it; tcin-yēutl-nūq, I burnt it up, *i.e.*, consumed it entirely by fire.

tcin-kōas-atc, I burnt my hand; tcin-kōaskōas, I am burnt.
tcī'atl ī'-mē tcēEk tE tlk·aitc, the moon will rise soon.
tcī'atl ī'-tlēEk, he will come soon.
tcī'atl tcin-ī-nâm, I must go soon.
ens-ku'lūān unkū Esk·ō'i, I think I am sick.
ens-ku'lūān Esk·ō'i-En-Ek·, I think I am going to be sick.
tcin-maqtl, I am hurt; tcin-tī-maqtl, I have been hurt.
nētl Esūā st'kai'ū, this or that is your horse.
hau'ōq or hau'ōk· tcētcEm-auq? can you swim?
sūat kūē nE tās ti? who made that?
ensī' nE tās, I made it, or shortly, ensī', or mEn uns, or nētl uns, I did.
tcin-tsa-nūq tEn k·ōmōqkcEn, I hurt my ankle (done by self).
'n-tsa tEn k·ōmōqkcEn, I hurt my ankle (done by some one else).
nE ī-qōī-nūq-ūās, he has killed it.
nE qōī-nūq-ūā-s sEn sk·umai', he has killed my dog.
nE hōī-nūq-ūā-s, he has finished it.
nE-hōī-nūq-ūā-s-wēt-Ek·, they will finish it.
nētl-sī nāo'n hātl, this is the best one.
hauq E'sūa sE st'kai'ū, this is not your horse.
tcin-qō'ī-nūq tE mEnī'tl, I killed him (ā'tlī mEnī'tl = her).
tcin-qō'ī-nūq ē'tsi mEnEnī'tl, I killed them.
'ntcauq kūEsEs mē tEn lām, once he came to my house.
'ntcauq kūEs nE mē tEn lām, once you came to my house.
tlē'Ek·t ū'ā-tlē'Ek tEn lām, he often used to come to my house.
tlē'Ek·t tcin-t-ūā nâm, or tlē'Ek·t kūEns ū'ā nâm, I often used to go.
nō'a or nau'a qēaqaiEm, he or she is laughing.
nō'a qEm, he or she is crying.
nō'a lō'lEm or yūwē'nEm, he or she is singing.
pEnaq-ūā-s tE ā skūa'lEwan, she is sad; *verbatim*, she has a sore heart.
tcin-pEna-nūq tE ā skūa'lEwan, I am sad; *verbatim*, I have just got a sore heart.
tcin-ē'-apis tE ā skūa'lEwan, I am always sad; *verbatim*, I am holding a sore heart.

ē-tci't-t-ūā lō'lEm, we have been singing.
nō'a sātsauq-wēt, they are happy.
nētl tlE Mary, it is Mary.
nētl tE Harry, it is Harry.
mē'ska tlEn yā'sīauk·, give me my hat.
nō'wēt yū'itl, they are making a fire.
yū'itlkāā', make up the fire.
hauq mēk·auq hau'a tlE uns? will you come with me? (woman speaking).
nE-t-ūā tlEtlEmōq, it has been raining.
ō-tcūq-ūā-kūilic tE sQēcen? did you shoot a deer?
nuk·tlEk· kwē, it is dark.
nō'a tē'Ek, or tē'kūaiEk, it is cold.
nuk·qE'qEn or EsqE'qEn, it is frosty.
yē yEk·, it is snowing.
nE mEn tlā'tlum kūi tci'lāqtl, it rained all yesterday. (In speaking the first syllable of tlā'tlum is drawn out to mark continuity of action.)

stām k·ūē'-ūā Qoistauq? or stām kūā Qoistauq? what are you eating?
tcin-kūātc-nūq kwīkwōkwent, or kōkwentl unkūātc-nūq-ūā-n, I saw him a long time ago.

nE u'ntca kōEtl nō'ā nā' or nānā'? where do you live?
QElētEn tai, he is a white man.
pEk stlānai, she is a white woman.
yūtl-ka, light a fire.
yākūEtcp-ka, make up the fire.
hau'Ek hauq sōm-nūq? can you smell it?

(N.B.—It will be noticed in all these questions that the Sk·qō'mic invariably use the negative forms 'can you *not*,' &c.)

tcin-stcūāt kūē lō'lEm, I know how to sing.
k·eq tEn slēl, I have some blankets; *verbatim*, plenty my blankets.

ā'anōs tEn st'kai'ū, I have two horses, *verbatim*, two my horses.
hauq Ensūas 'n snūkūi'tl, this is not my canoe.
tōitEntsōt-tcuq kūEs ē-ūā-sk·ō'i, or hātl kūEs tōitEntsōt kūEs ē'ūā-sk·ō'i, when you are sick you should take medicine, or it is good to take medicine when you are sick.
ō-tcūq-Esk·ō'i ? are you sick ?
ūā-tcan, I am.
ō-Esk·ō'i ? is he sick ?
ō-tcūq kōa'sī ? are you warm ?
k·Qātles kūEs kūail Ek ·kūailEs nâm-tcit-Ek·pī'atūtl, or pīpla'tūtl, if it is fine to-morrow we will go out hunting.
k·auq-tlēEk satcit-tōmī-tcin, if you come I will give it to you.
Esk·ō'i-tcan-k· HEnhōis ti, if I eat this I shall be sick.
ōk·hauq kūātl tE ninā' ? is your father dead ? *verbatim*, is not he-who-cared-for-you gone by ?
ōk· hauq k·'sitl ā'tlī ninā' ? is your mother dead ? *verbatim*, is not she-who-loved-you gone by ?
ūā-sūat lām ti ? whose house is that ? (N.B.—If house be distant from speaker, he adds ēna = yonder.)
ōk·ōEmē' or ōtlē'tlEk ? is he coming ?
ē-ōk· tlētlEm-uq ? art thou coming ?
tlē'Ek·t tcin-ūā Esk·ō'i, I am often sick.
ōīs-ka (from preposition ōīs = in), go in.
kūEns-e-ōīs nE Esqai'ts tE suē'ka na tE slauē'n, when I came in the man was lying on the bed.
kūEns nE-nâm ōtsk· ē'kuē tcinkūātc-nūq nE tai, when I went out I saw him there.
'nslē kūEs nâm, I want to go.
mē'Eka, come along.
tcin-ūā skō tEn etltatc, I live or stay with my parents.
tcin-ūā ē tlEn (or tEn) tsā'ata, I stay here with my aunt.
tcin-ūā nE tlEn tsāata, I stay there with my aunt.
hauq nētlEs Ensūa 'n skapitē'ūq, this is not my knife (carving).
tsē tlEn sōk·ōi na tEn lām, I have some fish in the house.
tsē tlEn (fem.) smēts, I have some meat.
ō'pEn te lām nE tanū'k-ūā-n, I have built ten houses.
Hōiska tcatūī'tl, let us make a canoe.
Hōiska nâmnâm, let us go.
Hōi kētl, all right.
Hōi-ka Hōis tsi, let us eat it.
Hōi-sk-it-ētlEk-cEn, let us make moccasins.
tōtau tE tlk·aitc, the moon is bright.
tcin-Etlskais tE stElmūq, I know that person.
mē-ka tE st'kai'ū, give me the horse.
ō'tcūq tsō'tlEm ? are you cold ?
ō'-tcūq k·ōi or kōak·ōi ? are you hungry ?
tcin-Etlskais kūē sk·ō'tūt, I know how to run.
QEn- or HEn-Etlskais kEs u'ntca tcin-k·-sā'tcīt-tōmī, if I knew where it was I would give it to you.
QEs or HEs tlā'tlumQ hauq ūā-n-nâm, if it rains I shall not go.
Hō'iska tE sō'k·ōi, eat some fish.
mē'kati, come here.
mēauka, come.
sūat tcūq ? who are you ?
nE-tcan-kwōīts or nE tcan-kwētlEn, I have eaten my dinner.
tEmī', go away.
mē'ka ō'is, come in.
amō'etka, sit down.
m'ēka ō'is, tEn lām, come into the house.
tcin-kwatc-nūq tE sk·umai', I saw the dog.
mē'ka tcā'tla ō'is tEnlām, come into the house for a little while.
hauō'q nâm, don't go.
hauō'qmē, don't come.
tcin-k·ō'k·ōt na tE smōs, I struck him on the head.
kōk·uēn EtlEn kwatc-nūqūān ā'tli, I saw her a long time ago.

'n slē kūᴇns nâm, I want to go.
hauq kunslē'as kūᴇns nâm, I don't want to go.
nᴇtl untca kōēē' st'kai'ū? which is your horse?
tcin-tᴇm-cᴇn, I cut my foot (with axe).
tcin-tlatc-cᴇn, I cut my foot (with glass, &c.)
tcinā'tli, I hurt myself.
tcīn-maqtl, I am hurt.
tcin-i-ē'tlᴇns, I made him eat it.
tcin-ī-kwī'at, I made him stop.
tcin-mᴇn-tcisᴇn, I made him go.
tcin-ī-ēm kūᴇns nᴇ wēuk·tᴇn, I made him tell me.

PARTICLES.

Of the various particles which enter into verbal syntheses, there are two in particular which deserve special mention. These are *nᴇ* and *nūq*. The former has an independent existence as an adverb of place, meaning 'there.' The latter I have not found apart from the verb. The functions of *nᴇ* are various, and at the outset of my studies I found it very perplexing. It marks, like *tlum* in the N'tlaka'pamuQ, the absence of the thing spoken of; it marks absence in the third persons when they are the subjects of conversation, and it marks absence in time also, both past and future. As may be seen from the paradigms of the verbs, it is the regular sign of the past indefinite. It occurs also in such phrases as 'next morning' = *nᴇ-k·ōā'il*. *Nūq* was also a source of trouble to me at first. In writing down phrases to bring out the inflections of the transitive verb, I found that the verb 'to strike' (*k·ōk·ōtᴇs*) was sometimes given to me as *k·ō'k·ōt*, and sometimes as *k·ō'k·ᴇnūq*. The explanation given me by one of my informants only misled me. She did not understand it herself. After further study and comparison it became perfectly clear. I found that *nūq* could be affixed to every transitive verb. Its functions are exceedingly interesting. Primarily it is employed by the speaker to inform you that the action spoken of took place without his knowledge or observation if done by yourself, and if done by some one or something else without your knowledge or observation as well. For example, I may desire to tell you that I have hurt my face when doing something. If you are present at the time and observed the accident I should use the form *ē-tcin-maqtlos*, but if you had not observed it or were not present when it happened and I wished to tell you of it, I must then say, *ē-tcin-nūq-maqtl-os*. Again if I desired to tell you that I killed ten deer yesterday when you were absent, I must say *tcin-kōi-nūq tᴇ ōpᴇn*, &c. Or, again, I have just been told, it may be, that some one dear to me is dead of whose sickness or condition I was unaware. I am sad in consequence. If I am questioned as to my sad looks I must reply *tcin-pᴇna-nūq tᴇ ā skūa'lᴇwan*, which literally rendered means, 'I have just become possessed of a sore heart.' If my sadness had been of long standing, the cause of which was known, I should answer tcin-ē-apis tᴇ ā skūa'lᴇwan, which signifies that 'I am holding all the while a sore heart.' Other interesting examples may be seen in the story of the Smai'lᴇtl, given below, page 512, in the Sk·qō'mic text. In the paragraph where we are told that the girl saw the following morning that the slave bore the imprints of her painted hands upon his shoulders, the nᴇ-kwatc-*nūq*-ūā-s form is employed to express the surprise of the girl in learning that it was the slave's back she had painted. She had placed her hands knowingly on her ravisher's shoulders in the dark without knowing who he was, hence *nūq* was necessary here to mark her surprise. Another good instance is seen in the paragraph which tells of the chief's perception of his daughter's condition, *nūq* bei g necessary here to show that up to this time he had been unaware of what had taken place. A somewhat different function is given to it in the concluding paragraph of the story, where the descendants of the pair are said to be very keen-scented, the term *nūq-ē'ēᴇks-wēt* here literally meaning that they are able to smell things before they can see them or otherwise know of their presence. One of my informants gave me to understand that the 'k·ōk·ōt' form signified an accidental striking, and that 'k·ōk ᴇnūq' implied intentional or purposive action. I doubt much if this is correct, as the language contains regular purposive and accidental particles. For example, if I desire to say that I have been purposely struck by some one, I must use the following form of expression: 'ntsa-ānsās, 'he struck me with intention.' If accidentally struck then I say 'ntsa-numcis, 'he accidentally struck me.' Again, 'he struck me with a stick intentionally' is rendered by nᴇ k·ōk·ōtsis; but 'he struck me with a stick by accident'

by nE k·ōk·-numcis. Another interesting distinction between accidental hurt to myself by my own action and intentional hurt by the action of some one else is thus marked. If I want to say I have accidentally struck my eye and hurt it, I say tcin-tsa tEn k·ulōm, but if I want to say some one else has purposely struck my eye I must use the expression 'ntsa tEn k·ulōm. The difference of action is here brought out by the use of different pronouns. *mEn* appended to a verb stem signifies duty or necessity = our 'must' or 'ought.' Before leaving the particles it will be of interest to point out that *hō'i*, the regular sign of the future in the N'tlaka'pamuQ, is seen in the Sk·qō'mic dialect only in exhortative forms, while the Sk·qō'mic future *Ek·* is, as far as I am aware, wholly absent in the N'tlaka'pamuQ.

PREPOSITIONS AND PREPOSITIONAL PHRASES.

On the beach, *na* tE ai'utlk·.
Near the house, *tcēt* tE lām.
In bed, *na* tE slauwēn.
On a stone, *na* tE smant.
Put him to bed, nâm-ka aqē'ts; *verbatim*, send him to lie down.
Put it in the box, nūEnka tE kūa'kūa
Under a stone, *lus'īwētl* tE smant.
Across the water, tE *ē'tlaka* tE stauq.
On the other side of the water, tE *ē'tlaka mins* tE stauq.
Far over the water, nE-q*uta tsa* tE stauq.
Up in the sky, tE *tcētl* skwai'yil.
I found it near the house, tcin-ya'kEnūq *tcēt* tE lām.
Sit on the ground, āmō'etka *na* tE tE'muq.
Come to me, mē'ka *tla* uns.
Go in the house, *oiska* tE lām.
Go in, *ō'is*-ka.

CONJUNCTIONS AND CONJUNCTIVE ADVERBS.

and, *ī*; *īkwī*, and, plus; *ēkwina*, then; *yātlsis*, so, therefore; *nētlmutl*, therefore *smEn*, so then; kūEsE's, when.

TE Smai'lEtl Sōq'wīā'm.

(The wild-people story.)

'ntco sīā'm nE â'tlī-mEns nânā' tE skwīō'ts. TE skwīō'ts nōā-Esqai'ts
One chief once daughter-his lived (and) a slave. The slave he is lying

ustā't'k· na tE watcEns ā'tlī-kā'mai. TE skwīō'ts nō'a-nâm ekqē'ts. Nâm
crosswise at the foot-hers maiden. The slave he-is-going to-ravish-her. He goes to

ā'tlī kā'mai. NE-pEna'q-ūā-s tE sē'aQotl. Hauq-wetl sk·ē'stEs kūEs tE skwīō'ts
maiden. She-conceived a child. Not yet she-knows that the slave

ē'-ūā-tlē'Ek·unt. NE-kwa'tc-nūq·ū'ā-s tE sīā'm kūēsE's Esk·ō'ī ā'tlī-mEns.
had-been-coming-to-her. He perceived it the chief when sick daughter-his.

Ē'kwina pEna'q-ūā-s tEs ē'aqi. Stlēs kūEs tEl-nEk-ūā-s-Ek· sūā'tEs
Then he-gets-it the-his shame. She-desires that she-will-find-out who-it-is

kūā-hEmēnit. Yātlsis qE'l-tās tE nāqtc tE spE'tltEn.
that-may-have-been-coming-to-her. So she-makes-paint-on the hands the paint.

Nē'tlmutl kūEsE's kū·atlē'Ek ē'kwina kā'ātctcantEs nok·qE'l tE
Therefore, when he-may-come then she-puts-her-arms-about-him marking the

staitcs. NE-k·ōā'il nE-kwa'tc-nūq-ū'ā-s kūEs nētl tE skwīō'ts nE-sqoqE'l
back-his. Next-morning she-perceived that it is the slave she had marked

tE staitcs. KūEsE's tEln'Ek-ūā·s tE tcētct ē'kwina ō'iyutlstEs tE snukūī'tl
on the back-his. When he-finds-out the father then he-takes-into the canoe

tlE mEns ī tE skwīō'ts. ē'kwina ē'sōn-wēt. SmEn-tsē'auq. tE
the daughter-his and the slave. Then they paddle-off. So-then-they-arrive-at a

stātā'Qais. ē'kwina k·ōm-stum-wēt. SmEn-tō'EntEm. Hauq sūāt Eskai's
very-lofty-cliff. Then he-landed-them. So-then he-left-them. Not anyone knows

Qaswitca'nEm ē'kwina wēt-k·qai. SmEn-nâm-wēt ē'mac. SmEn-
in-what-manner then they-got-up. So-then-they-went-on walking. So-then-

tsē'auq-wēt tE qā'tcō. SmEn-tāstās-wēt tE lām-swēt. ē mē koqā'i
they-arrived-at a lake. So-then-they-made a house-their. Here came many

tE mEmE'n-s-wēt. Mē'cōi. ē'kwina mEn-pētwai'-wēt. ē'kwina EsmE'nwēt.
the children-their. They-grow-up. Then they intermarry. Then they-have-children.

ē'kwina k·qai'-wēt ō'k·wumūQ. Eskōai' kūEs Qēs tE snē'tcEm-s-wēt. Sk·qō'mic
Then they-become a village. Never is lost the language-their. Sk·qō'mish

kūEs ūā-snē'tcEm. Hīyē'sīwē'Eka. nūq-ēē'Ekswet. ē'auq nok·wē'ak·tEn
it is they-spoke. Very tall men. Very-keen-scented-are-they. They-wear undressed-fur

tE yEkwai-s-wēt. Tēmā-wetl sūā'ō tE sna-s-wēt Smai'lEtl.
the garments-their. Hence thus the name-their wild-people.

VOCABULARY.

man	suē'ka
men	sīwē'Eka or sēwēEka
woman	stlā'nai
women	stlintlā'nai
boy	suēkaō tl *or* skuē- [kaō'tl
youth	suē'wolōs
maiden	k·ā'mai
girl	stlānaiō'tl
little boy	āam'
„ girl	āa'mc'n
infant	sk·ā'k·El
child	stāō'tl (sē'aQōtl pre-natal term)
children	stūtāō'tl
middle-aged person	nuk ē'yE
old man	(tai) sEūīōqwa, stlmōt (plu stltlmōt)
„ woman	(ā'tli) sEūīōqwa, stlmōt (plu. stltl-mōt)
very old man	kā'ēlEn, kaiē'lmūq.
mother	tci'ca, kē'īa, tā'ā.
father	ma ma, tcētct.
son	mEn (tEn = my).
sons	mEnmEn (tEn = my).
daughter	mEn (tlEn = my).
daughters	mEnmEn (tlEn = my).
sons and daughters (collectively)	mEmEn.
husband	kwoto'mps, skō', when called by wife nō'ā.
wife	tcūwa'c.
several wives of one husband	tcūtcū'wac.
wife when called by husband is termed	nau'.
parents	Etltā'tc.
grandfather	sē'la, sīl, tsē'El (tai).
grandmother	„ „ „ (ā'tli).
grandparents	silsē'l.
grandson	ē'muts.
granddaughter	„

grandchildren	umē'muts.
aunt	tzā'ata (if mother or father be dead then the aunt is termed sai'ūq or wotl-sai'ūqatl, but when both parents and aunt are dead then the aunt is spoken of again by the term tzā'ata; the same applies to uncle also).
uncle	sē'saē.
step-father	sūā-ma'n.
step-son	sūā-mE'n (tEn).
step-daughter	sūā-mEn (tlEn).
son-in-law	sāq.
father-in-law	sāq.
son-in-law-elect	stūta'tl.
daughter-in-law	sāq.
mother-in-law	„

N.B.—This term sāq is changed to *slēak·wai'tl* if relationship be broken by death of son or daughter.

uncle's wife	sūa-tcica (= step-mother).
aunt's husband	sūa-man (= step-father).
elder brother	kō'pits.
elder sister	„
elder cousin	„
younger brother	sk·āk·.
„ sister	„
„ cousins	„

N.B.—If aunt and uncle are older than parents, then cousins are termed *kō'pits*; if they are younger than parents, *sk·āk·*.

brother's *or* sister's child	stai'atl, changed to *sonīmai'tl* if mother or father be dead.

brother-in-law	tcima'c (plu. tcimtcima'c).
sister-in-law	tcima'c (plu. tcimtcima'c).

N.B.—This term is applied alike to wife's or husband's brothers, sisters, and cousins, but when the connection is broken by death they are no longer called *tcima'c* but *tcāi'ē* (plu. *tcitcāi'ē*).

The relatives of sisters-in-law, brothers-in-law and cousins-in-law are termed *kūē'was* (plu. *skūikūē'was*), but when connection is broken by death of intermediate relative they are then called *kūintlūaqām*, which signifies that both sides are crying or grieving.

widow	sīā'ātᴇn (ā'tli).
widower	„ (tai).
orphan	wā'nim (ā'tli or tai, according to sex).
lover	sī'yā.
eldest child *or* first-born	sēntl.
second child	u'nōntitc.
third „	unwi'tl.
youngest *or* last	saut.

N.B.—The term *unwi'tl* is applied generally to the middle children, the plural form being *ununwi'tl.* The younger ones are also spoken of collectively as *sᴇ saut.*

darling	s'kō'nuk· (term of endearment used by mothers in addressing their children '*t'lᴇn s'kō'nuk·*' = my pet or darling).
	s'tā'cᴇm (term borne by children of a female slave by her master; also a term of reproach).

Children of one father by different mothers are known by term *sintcō'ītl.* One half brother or sister would say of another, in speaking of him, he is my *sintcō'ītl.*

Children of first cousins are all regarded as nephews and nieces, and first cousins' children's children are consequently regarded as grandchildren. Relational ties extend with the Sk·qō'mic to six generations on both sides of the family. These are known under the following terms:—

mᴇn	child.
man	father.
tci'ca	mother.
tsēᴇl	grandfather or grandmother.
stcā'mēuk·	great-grandfather or great-grandmother.
tsū'pīyuk·	great-great-grandfather or great-great-grandmother.
hau'qkwīēuk·	great-great-great-grandfather or great-great-great-grandmother.
smᴇnā'tl	princess (a title commonly given to chief's daughters and also applied to other girls as a term of honour and praise if they were good and industrious).
Indian	stᴇ'lmūq.
person	„
people	tᴇ tstᴇ'lmūq.
chief	sīā'm.
village	tᴇ ō'k·wumūq.
head	s'mōs.
face	tsā'tsus.
hair (of head)	sk·ō'mai.
„ (on body)	skē'nus.
„ (of animals)	tā'min.
beard	sk·ūē'intz.
forehead	stōktcūs.
jaw, chin	sk·wawa'ctck·.
top of the head	nukaiī'tsīēk·.
side „ „	nukmīyē'wāᴇn.
back „ „	staiā'psum.
tooth	yena's.
nose	mu'k·sᴇn.
bridge of nose	nukau'kūts, n'cauk·s.
ear	kwo'lun.
tongue	mᴇkā'luçeltl.
eye	k·ulō'm.
mouth	tsōtsin.
gums	smē'tsans.
upper-lip	stcēlts.
lower-lip	slusts or tlusts.
eye-brow	sō'mun.
eye-lashes	tsē'ᴇptlᴇn.
skin (human)	k·uolau'.
„ (of animals)	k·wē'kᴇn.
throat	qōmntl.
neck	ku'nauq.
back of the neck	sukā'psum.
back	staitc.
chest	sē'lenus.
breast	sk·em.
teat	saiks (=point).
bosom	stelkwām.
stomach	kōᴇl.
navel	mō'qwīa.
body	slā'lau.
liver	tluk·tᴇn.
marrow	nᴇkwo'cin.
arm	taqūntᴇn, naqtc.
hand	tcīē'putc, naqtc.
elbow	tsai'ksai.
shoulder	cītliā'met.

finger	nēaqō'Etc or nēaqō-yatc.
finger-nail	qQīqōī'Etc.
thumb	sēntlqoyatc (=eldest finger).
first finger	tauqo'stEn (='the pointer').
second ,,	su'nawitlō'la = (one before the middle one).
third ,,	unawi'tl (= 'the middle one').
little ,,	saut-kō'la, or saut-qō'yatc (=youngest finger).
thigh	smū'kwalup.
leg	stcīē'psen.
knee	kwinē'ukcin.
ankle	kwo'mōk·cin.
foot	sqEn.
sole of foot	nūkū'ācin.
heel	sai'k·cin.
toe	stcīēpkūō'cin.
toe-nail	quō'quōcin.
skull	cauk·.
fat, oil	sQus.
guts	k·aiya'q.
grease	Qus.
heart	tsā'li, sk·um.
heart (as seat of the affections)	skuā'lawān.
blood	stsā'tsīEn.
mind	skwā'lawān.
breath	tlā'k·ōm.
dream	sElu'li.
canoe	snE'kūitl.
paddle	sk·um'l.
house	lām.
'potlatch-house'	tlāanukautu'Q.
a house with carving upon it	stcu'tuQ.
fire	yēutl.
cinders	pē'tcit.
ashes	nukwiyē'utl-tEn.
smoke	spō'tlam.
flame	slē'itzum.
soot	kwai'tcup.
fire-making implements	stcī'tcup.
sky	skwai'yil.
sun	snu'k·um.
moon	tlk·ai'tc.
full-moon	nu'qkutc tE tlk·ai'tc.
half-moon	nu'qsetkutc tE tlk·ai'tc.
star	kō'sen.
clouds	sk·ātl.
light (of day)	kōa'kēl.
,, (of moon)	astlkai'tc.
,, (of stars)	askō'sen.
,, (of torch, &c.)	aswātcit.
,, (opposite of dark)	tō'tau.
dark	tlEk·.

dawn	ma'tciEk (= light coming).
morning	nātl.
evening	nā'net.
day	skō'ēil or skwai'yil.
night	nāt.
sunset	kunp.
twilight	tla'tci.
noon	tuk skwai'yil.
rain	stlumōH.
snow	mā'k·a.
hail	qōqo's.
ice	sEō'kEn.
frost	Hu'qun.
water	stāk· or stauk·.
sea	kōtlkq, squn.
river	hī'yē stauk· (=big water).
lake	qā'tcū.
stream	swalt.
earth, land	temē'q.
wind	spEhē'm.
mountain	smā'nēt.
hill	cē'tlōs or stcē'tlōs.
stone, rock	smānt.
wood, tree	tsuk·.
fire-wood	yā'utl.
trees	tsuk·tsuk·.
leaf	stcō'ltla.
sap	ts'qāmts.
branch	st'kā'tcū, QēQolā'tcoq.
bark	slai, 'pulí.
root	t'kwā'mīanQ.
grass	sāqwai.
berry	sk·wolā'm.
meat	smēts.
flesh	slē'uk·.
horn	tsē'istEn.
bow	tō'qoatc.
arrow	s'māal.
salt	tlās'tlEm.
axe (stone)	tlak·a.
now	tE watsōmtl.
to-day	tE sīs or tsīs.
yesterday	tE tci'lāqtl.
next day	nE k·ōā'il.
to-morrow	tsk·k·ōā'lEs.
next month	kōi 'ntcō' tlk·aitc.
last year	kōit pā'nō.
next year	kōi 'ntcō' selā'num.
good-bye	hōīmEtla'tl.
lightning	t'qai'ūs.
thunder	ēnīnyā'qEn.
name	snā.
medicine	tō'it.
medicine-man	sQōm'tEn.
blanket (native)	sōk·ōetl, slēl.
,, (white)	pEk·u'lwit.
a covering	hu'mtEn.
fog	sk·wo'tcum.
current	sqōm.
rapids	,,
sand	k·wEpē'tcin.

hunger	ahā'nōm.
shame	ē'aqi.
love	instlē.
shadow	kēnkēnHu'na.
wisdom	nEkaiē'lEs.
help	tcauEltEn.
work	sitsā'p.
swamp	mā'kwom.
spoon	tcau'ai.
soup	stlōm.
sorrow	sE'sulkQ.
joy	tsā'tsauq.
rope	Qē'lEm.
platter	tlEkqai'tstEn.
potato (native)	skauē'setl.
,, (cultivated)	skauts.
spear (salmon)	sEnā'm.
snow-shoe	k·la'lcin.
strawberry	s'tcē'i.
wing	ye'lāEn.
valley	nūklEsā'm.
tears	nEkwō'ōs.
sweat	yā'kwom.
tail	skwō'kūts.
voice	nūknē'tcimtEn.
staff (walking)	t'tcātc.
a whistle	sk·wō'kElEm.
maple-tree	k·u'mElai.
willow-tree	qai'yai.
cedar-tree	Qāpaiyai.
cedar	Qāpai.
cedar-platter	Qāpīyō'itl.
alder-tree	klō'lai.
elderberry bush	tsē'wok·ai.
salmonberry bush	yittwā'nai.
basket (general term)	sē'tEn.
basket (big, for gathering herbs, &c.)	Qok·ō'lstEn.
bag	tlāpā't.
bay	sā'tsEnutc.
dew	stlEmtlEm.
drum	mEnā'tsi.
belt	nuqyi'mtEn.
eggs	auQōs.
bed	slauwē'n.
box	kōa'kōa.
beach	ai'utlk·.
spring of the year	kōā'kōEsi (= growing warm).
summer time	tEm kōa'skōa's, temīē's (= hot season).
autumn	tetakwi (getting cold).
winter	tEm tēq (= cold season).
time *or* season	tEm.
down	nē'ak·ō'mai (= soft hair, *cf.* hair).
feathers	sl'pā'lkEn.
door	n'ku'ptEn.
window	kwotcōsenau'tq.
garden	nE-pEnmai'.
fern	sQōtluk·.

ghost	cai'u (= screech-owl, *see* under 'Beliefs.')
life	aī'nuq.
soul, spirit	taQatlai'nuq.
God	tcītl sīā'm (= upper or above chief).
noise (made by children)	tcē'ānsut.
noise (of talking)	snā'-nsut.
scissors	tzu'mk·tEn.
needle (weaving)	tca'msutEn.
alder-bark basket	pīā'kō.
net	sHōkwētcin.
tent (of mats)	stlwāmts.
witch	sīū or syū.
fruit of the elder	tsē'unk·.
sound	kō'min.
fish-rake	tli'tamEn
promontory (*cf.* radical for nose)	sk·u'tuksEn.
clam-digger	skulq.
chisel	Qohai't.
cedar kettle	sçum.
cedar-platters	Qāpīyoitl.
barbed spear-point	mīātc.
salmon-trap	tcēa'k· *or* tcīak·.
feast	klāa'cEn
knife	tlatctEn.
needle	patctEn.
saw	tlītctEn.
salmon-knife	Qē'itctEn.
nest	tsētsipē'tltEn.
moss	kwīyā'm.
mud	tsēk·.
log	kwEltlai.
milk	stilkwē'm.
moccasin	slu'k·cin (also mūkōcin).
friend	sīai'.
fur	k·wē'Ek·tEn.
gall	mE'sEn.
iron	cūpa'lEtEn.
east	tilu'tsnitc.
west	tiltē'wit.
north	sō'tic.
south	tEmtca'uq.
round	cē'citc.
raw	tōē'n.
happy	tsā'stauq.
poor	Estsā's.
I am poor	tcintsā's.
slow	ō'yōm.
sharp	ē'yōts.
long	tlak'it.
short	ātlē'm.
strong	īē'm.
sweet	kā'tEm.
broad	tlekā't.
thin, narrow	Ek·ōās.
lean	tEtī'ts.
new	qaus.
white	pEk·.
black	k·Eqk·ai'q.
red	kwo'mkēm.

yellow	tltc.
green	tlEstlēs.
large, big	hīyē′, eya′.
small, little	utse′m.
strong	ēyē′m.
weak	kulē′m.
sore	ā.
dead	k·′ō′i.
sick	Esk·′ō′i.
dry	tcēQ.
good	hātl.
bad	k·ai (plu. k·ai′ak·ai).
beautiful	nEtcē′m (plu. nEtc-natcē′m.
cold	tēq.
warm, hot	kōas.
all	ēq
some	kōēn.
much, many	k·āq, k·eq.
yes	ē, ēh.
no	hau.
not	hauq.
never	hau′tcin.
rotten	ts′ūq.
above	tcītl.
below	kūElus.
far	qu′ta.
near	tcēt.
this	ti.
that	,,
these	ē′tsi.
those	,,
the	tE (masc.), tlE (fem.)
anybody	swat.
who	swat.
which	u′ntcakōē.
then	ē′kwina.
thus, so	sūā′ō.
therefore	yātlsi′s.
at, on	na.
when	kūēsE′s.
where	nE.
to cry	hām.
,, dance	mē′tla.
,, eat	kwō′its, kwē′tlEn, ē′tlEn, Hōis.
,, come	mēkat, tlē′Ek, mē.
,, gamble	g·ā′g·Eltq.
,, call	kaiEtEn, ō′ētka.
,, dig	tEkwon′p.
,, find	yā′kEn.
,, hunt	pī′atōtl.
,, shoot	kwila′c.
,, work	zētza′p or ′sitsāp.
,, swim	tcē′tcEm.
,, run	skā′tzut.
,, sing	slu′lō, lō′lEm, yū-wē′nEm.
,, laugh	qai′hEm, sqai′aqai.
,, point at	tau′qōs.
,, whistle	cō′pEn.
,, whisper	tlā′kEm.
,, vomit	yīa′t.
I am sick	tcinyīa′t.

to strike	k·ō′k·ōt.
,, go	nâm.
,, talk	snē′tcEm.
,, boil	wotlkEm.
,, spoil, waste	kElkElē′l.
,, fight	kwē′ltEn.
,, fight in battle	kai′Ek·entwai.
,, see, perceive	kōātc or kwātc.
,, bruise	sauq, pēt.
,, burn	kōas.
,, burn up	yē′utl.
,, hurt	tsa, maqtl.
,, sit	amō′et.
,, cut	tlatc, tEm.
,, want, desire	slē.
,, kill	kō′i, qō′i.
,, love, like	tlē, stlē.
,, build	ta′nūk·.
,, know	Etlskai′s, Eskai′s.
,, give	sā′tcit.
,, smell	sōm.
,, get, have, hold	pE′naq.
,, finish	hō′i.
,, make	tās, tā′stās.
,, think	ku′lEwān.
,, lie down	Esqa′its.
,, find out	tE′lnEk.
,, paint	qE′l, qE′ltās.
,, paddle	sōn.
,, arrive	tsēauq.
,, land	k·ōm.
,, walk	ē′mac.
,, speak	snē′tcEm.
,, leave, quit	to′EntEm.
,, lose	Qēs.
,, agree to, consent	ānō′tl.
animals (as a class)	sōqōqē′muq.
frog	wā′qus.
duck (generic)	qēlē′Ek.
eagle	yaQe′la.
wren	Qit.
humming-bird	titc-titcEnīs.
rat	hauwait.
mouse	Qōā′tEn.
flea	tō′tlum.
louse	me′tcin.
nit	Qusta′n.
house-fly	ā′qūai (plu. oqā′qūai).
mosquito	k·wanē′matc.
dog	sk·umai′.
horse	st′kai′ū.
bear (black)	mī′aqutl.
,, (brown)	k·tlalum.
,, (grizzly)	tlatla′lEm.
deer	sQē′cen.
wolf	t′k·ai′ā or tEkaiyā.
beaver	sk·Elō′, or sk·Elau′.
elk	k·iā′tc.
moose	kwā′ta.
woodpecker	′skēEks.
screech-owl	cai′u.
loon	swā′kwil.
goose	Eqa, tlaukqun.

gull	k·waiē'tEk.
fish	sō'kōē, ōtsō'k·ōi.
crow	k·lā'k·a.
owl	tcī'atmuq.
squirrel	smEmElō'tsin.
snipe	spEpEla'tc.
seal	āskQ.
robin	'skwEkā'k.
rabbit	sō'hōpēt.
porcupine	kwō'kwosEm.
pigeon	insāqā'qEm.
partridge	mō'mtEm.
mink	tcitcē'Ek·En.
grasshopper	insatsatsētqun.
kingfisher	ts'tcE'l.
spider	sHōHōkwē'tcin = net-maker, *cf.* sHōkwē'tcin = net.
swan	'swō'ken.
worm	tsuk·Q.
bee	sisamai'.
ant	tsitsamē'tcin (name has reference to its slender waist).
bat	kapkapsai'tl (= the smotherer, so called because the Indians believed it would settle upon the mouth and nostrils of a sleeping person and smother him).

Marine Terms.

salmon ('spring')	kōs.
„ ('sockeye')	tsu'k·ai.
„ ('cohoe')	tsā'win.
„ ('humpback')	tlau'ētcin.
„ ('dog-salmon')	kōā'k·Enis.
salmon ('steel-head')	skē'uq.
salmon-trout	sīu'ūiqkō'lō.
brook „	tlE'tlēukōai'.
codfish (black)	ai'Et.
„ (rock)	tsācilē'uk.
„ (red)	tūk·to'q.
'tommie-cod'	tsu'mkōā.
sturgeon	sk·ōa'watc.
oolican *or* candle-fish	sīūwas.
whiting	kuē'īātsun.
flounder	po'ai.
herrings	slaut.
smelts	s'tcā'k·um.
oyster	tlauqtlauq (*cf.* tlauq = hard).
mussel	tlau'akum.
crab	qai'Eq.
eel (conger)	n'satctcauEm.
'bull-head'	sE'nai.
clam (generic)	tsā'qūā.
„ (large kind)	sQām.
„ (small „)	sk·unts.
cockle	stlō'um.
sea-eggs	skōē'tsai.
star-fish	tō'muktl.
sea-cucumber	Ela's.
'devil-fish' (octopus)	stloqts, skē'amuq.
whale	kwinī's.

Canoes.

big canoes, commonly called Chinook canoe	k·Qō'Etl.
medium-sized canoe	sni'tc'l'p.
small	pElā'tcEm.
common	snukūī'tl.
old	sk·aiō'īūītl.
new	k·ōqūī'tl.

FOLK-LORE.

Qais.

Once there were four brothers[1] named Qais who went about the country doing wonderful things. It was very long ago, when the animals were human beings.[2] They usually travelled on the water in a canoe. This canoe was not an ordinary vessel. It was the youngest of the brothers transformed to this shape for the accommodation of the others. One day they came upon Deer, who was filing a bone to make an arrow point. They watch him at work for some time without speaking. Presently they ask him why he is filing the bone. Deer replies: 'I am making a sharp arrow point to kill a chief that lives some little way off.' From this answer the brothers perceive that he is a wicked person and deserving of punishment. So they straightway seize him and pull at his

[1] The name *Qais* in the story seems sometimes to be applied to the four brothers collectively and sometimes to the eldest only.

[2] According to the traditions of the Sk·qō'mic the earliest beings were animals with human or semi-human characteristics. In course of time the 'Great Spirit' brought the first true man into being, from whom are descended through many generations all the Sk·qo'mic people (see the writer's paper on 'The Cosmogony and History of the Skuamish,' *Trans. Roy. Soc. Can.*, Section II. 1897–98).

ears till they become long and pointed, and at his arms till they equal his legs in length. They then take the pointed bone he had been at work upon and thrust it into one of his feet, in consequence of which this bone (*smumk·sEn*) is found in the feet of all his bestial descendants to this day. After this they clap their hands and make a noise like a deer, and he instantly loses his original form and becomes a deer, with antlers springing from his forehead. Thus did Qais create the deer for the Sk·qō′mic. The creature starts off in fear and runs from them with the swiftness of the wind. When he had gone some distance he stopped and looked back, whereupon Qais beckoned to him to return. Said the eldest: 'He runs too fast; the people who come after us will never be able to catch him. We must make him go slower.' When the deer comes back to them they take him by the hind legs and knock his hoofs together several times. They then clap their hands again and send him off a second time. On this occasion he does not run so fast. 'That will do,' said they; 'he is all right now.' From here they paddle on till they come to an old man who appears to be fishing for salmon with a long double-pronged fish-spear. He carries also a big basket with him. The Qais stop and watch his proceedings. They find that he does not spear the salmon, but merely feels for them and rubs his spear against them, bringing away each time a little of the slime from their bodies. This he wipes off with some moss into the basket. When they see what he is doing they go up to him and take his spear away from him. From their pockets they then produce a *mī′ātc* (a barbed spear-point) and put it on the spear, saying as they do so: 'See, grandfather, this is the proper way to fish.' And as they speak Qais feels in the water with the blunt end of the spear for the salmon, and when he touches one he turns the spear quickly about and plunges it into the salmon. They then return the old man his spear and tell him to catch his salmon as they had shown him. The old man gets angry and says: 'I don't want you to tell me what I ought to do. I like my own method best, and I prefer the slime to the fish.' When he makes this strange statement they are convinced that he must be a person of a very undesirable character, who ought to be checked in his evil ways. They therefore take his spear from him and break it in two. The two halves they set against his legs one on each side. The point of the spear they push up his nose. They then pull at his head till his neck is much elongated, after which they clap their hands and utter the cries of a crane, and the old man is immediately turned into a bird of that species and flies away. Thus did Qais bring the crane into being.

They continue their journeyings till they come to a high bluff on the sea shore. Here they land, and the youngest resumes his own form. They now build a house for themselves and propose to stay a while there. When the house was completed the eldest suggests the making of a trap to catch the Sun. Said he: 'I will make a trap and snare the Sun. I want to have a talk with him.' He then transforms his youngest brother into a salmon, and secures him to the shore by a line; the salmon sports about in the water and looks a very fine fish. Presently Snu′k·um (sun) perceives the bait set for him, and descending in the form of an eagle pounces upon it and carries it off, breaking the line which held the salmon to the shore as he did so. The three brothers were unconscious of what was occurring, having been cast by Snu′k·um into a deep trance. When they awakened from their trance their youngest brother had disappeared. Qais was not to be beaten by Snu′k·um in this way, so he now transforms

the third brother into a whale and secures him in the same manner as the salmon had been fastened, only with a stouter line. No very long time after this Snu'k·um seeing the whale in the water came down and seized it as he had the salmon. Again the two remaining brothers are cast into a deep sleep. When the Sun had got up as far as the line permitted he was jerked back again to the water screaming. This continued till the brothers presently awoke. The eagle could not get away from the whale now because his claws had become entangled in the skin. So the two brothers pull on the line and bring the whale to the shore. Qais now said to the Sun : 'Don't try to get away, I want to have a talk with you ; that is why I set those traps for you.' When the Sun perceived that he had been outwitted by Qais he consents to stay a little while and talk with them. Qais now questions him concerning the place where the salmon come from. Snu'k·um points across the water and tells them the home of the salmon is a long, long way off in that direction. Qais tells him that he wants to go to the salmon country, and asks what he must take with him on the journey. The Sun instructs him to gather a great quantity of 'medicine,' and take that with him and all would be well. Qais now releases the Sun, who flies off into the clouds. Qais then set about gathering herbs for the 'medicine' which Snu'k·um had said was necessary for him to take, after which he and many of his people set out in their canoes for the salmon country. For many days they paddle in the direction pointed out by Snu'k·um and finally come to an island. This they are prevented from approaching by enormous quantities of floating charcoal which block the progress of the canoes. One of the young men, thinking the charcoal is compact enough to sustain him, jumps out of the canoe upon it, but instantly sinks through and is drowned. After much trouble they get away from the obstruction and paddle round to the other side of the island. Here they perceive what looks like a settlement. They see smoke of all the colours of the rainbow rising into the clouds. This is the country they are seeking, the home of the salmon people. They draw into the beach, which is very broad and smooth, and leaving their canoe go forward towards the settlement, Qais taking with him his medicine. When they arrived at the village Qais presented the chief, whose name was *Kōs* (spring salmon), with some of the medicine. Now at the back of the village was a creek in which Kōs kept a *tcēa'k·* (salmon trap), and just before Qais and his followers landed Kōs had bidden four of his young people, two youths and two maidens, to go into the water and swim round and enter the salmon trap. Obeying, they walked into the sea with their blankets drawn up over their heads, and as soon as the water reached their faces they became salmon and leaped and sported together just as the salmon do in the running season, making their way in their frolics towards the trap in the creek. When, therefore, Qais and his followers had landed and met the salmon chief, he ordered some more of his people to go to the trap and take out the salmon and cook them for his guests. This they did, cutting them open and spreading them on a kind of wooden gridiron to roast.[1] When the fish

[1] This gridiron was formed as follows: A shallow trench was dug about twenty inches wide, the length varying with the number of fish to be roasted, in which a fire of dry wood was kindled. On either side of the trench stakes were driven in at intervals. These were about three feet high. On the top of these, and parallel with the trench, were then fastened slender poles, and across these again directly over the flames other transverse ones. On these latter the split salmon were laid and roasted.

were ready Kōs invited his guests to partake of them, begging them at the same time to set the bones carefully aside and not lose or destroy any. The visitors accepted the invitation and soon disposed of the cooked salmon. After they had finished their meal some of Kōs's people came and carefully gathered the salmon bones together, which each of those who had eaten of the fish had piled in a little heap by his side, and took them down and threw them into the sea; whereupon the bones were immediately transformed back into the four young people again, who presently came up out of the water and joined the others. The salmon chief entertained his visitors with salmon-feasts for four successive days. Now the care which Kōs took over the salmon bones excited the curiosity of one of Qais's followers, who, on the second day, stealthily hid and kept back some of the head bones of the salmon he was eating. After the meal was over the bones were gathered up as before and cast into the water, but when the four young people came out of the water this time it was observed that one of the youths was covering his face with his hands. This youth went up to Kōs and told him that all the bones had not been thrown into the water, and that he was in consequence lacking the bones of his cheek and nose. When Kos heard this he inquired among his guests if they had thrown away any of the fish bones while eating, and pointed out to them the condition of his young man's face. The youth who had kept back the bones, alarmed at the consequence of his act, now brought them forward, pretending to have just picked them up from the ground. The day following the seagulls were seen to be gathering in great numbers about some object that was floating on the water a little distance from the land. Kōs sends some of his young men to see what the attraction is. They presently discover it to be the corpse of a young man. When Kōs is informed of the nature of the floating object he asks Qais if any of his party had been drowned; Qais answers that one of his young men had fallen into the water on the other side of the island and been drowned. Upon hearing this, Kōs bids his young men bring the floating corpse ashore with ropes. This they do, and Qais discovers that the seagulls have pecked out its eyes. Now although Qais had power to restore the corpse to life, he had no power to replace the lost eyeballs. So when he observes their absence, he asks the salmon chief if he could supply him with new ones. Kōs answers that he can, and offers him a pair of *Tsuk·ai*-salmon eyes. Qais tries these and finds them too small. Kōs then offers him a pair of *Tsāwin*-salmon eyes. But these also are too small. The chief then hands him a pair of *Kōā'k·ᴇnis*-salmon eyes, and these are found to be just the right size. Qais now sprinkles the corpse with some of his medicine, and the young man is immediately restored to life. On the fourth day Kōs makes a great *Klā'acᴇn* (feast), and gives to every one of his people a little of the medicine which Qais had presented to him. They were overjoyed to receive it, having seen its virtue exercised upon the corpse of the drowned man. During the feast Qais spoke thus with Kōs: 'I have come to visit you for the purpose of asking you to let some of your people come to mine. They are very poor and wretched, and have scarcely anything to eat.' 'Very good,' replied Kōs, 'I will do as you request, only you must take care of them and be careful not to allow any of their bones to come near a corpse.' Qais promised compliance with this request, and next day set out with his followers on his return. To Qais the time spent with the salmon people seemed only four days, but it was really a whole

year. As he was leaving Kōs said, 'I and my tribe will visit you first in the season.' 'After Kōs,' said the *tsuk·ai* (popularly known as the sockeye), 'I will come.' 'And after the *tsuk·ai* I will arrive,' said the *tsāwin* (cohoe). 'I will follow next,' said the *kōāk·Enis* (dog-salmon). 'I will come last of all,' cried the *tlau'ētcin* (humpback), 'and I shall not come regularly like the others, but just now and again.'

Hence, according to Indian belief, the irregularity of the runs of the last-named species.

When Qais got back he assembled a great concourse of people and told them that for the future they would have plenty to eat; that the Salmon had promised to come to them every year. After this he recalls that his youngest brother had been carried off by Snu'k·um and seeks to learn from those present if any of them could climb up beyond the clouds to Snu'k·um's house. They all reply that no one could climb so far. But among them was one cleverer and smarter than the rest, named *Tu'mtum* (Wren ?). He possessed a fine bow and many arrows. He now comes forward and says to Qais, 'I can shoot up there and make a chain of my arrows.' Qais was delighted with the plan, and bade him begin at once. *Tu'mtum* thereupon shoots an arrow into the clouds, and they hear it strike against the sky where it remained. He shoots again, and the second arrow lodges in the notch of the first. He continues shooting in this way, each arrow striking and fixing itself in the last until the chain thus formed reached to the ground. Qais now takes some of his 'medicine' and sprinkles it on the line of arrows, and the whole becomes rigid and stout and strong.[1]

Kōā'tEn, the mouse-man, now comes forward, and offers to climb up first. Qais consents, and he swarms up followed by *Tō'tlum*, the flea, after whom come *Me'tcin*, the louse, *'Skē'Eks*, the woodpecker, and the rest of the company. When they reached the summit of the ladder they perceive a big house. This was Snu'k·um's dwelling. They seek to enter, but find it securely fastened and too strong to break into by main force.

After some consultation it is decided to leave the matter of forcing an entrance to Kōā'tEn, Tō'tlum, and Me'tcin. Kōā'tEn sets to work and soon gnaws himself a hole to enter by, and the other two force themselves through a small crack in the boards. When they get inside Snu'k·um is just getting into bed. The fleas get into his blankets and worry him, the lice into his head and do the same, and the mice make such a disturbance that he is unable to get to sleep. They keep him awake tossing and turning till after midnight, and then being very weary he falls into a deep sleep in spite of them. They bite him again and again, but cannot wake him. Kōā'tEn then opens the door to Qais and the others. Qais discovers the head and bones of his brother, and returns to the ground with them. He now sprinkles some of his 'medicine' upon them, and his brother comes to life again.

When he had done this he pulled down the ladder, and many of those who were still upon it fell down and were killed. The Qais having come together again, the youngest resumes the form of a canoe, and they paddle away to another part of the country. On their way they come

[1] It is worthy of remark that in one of the Haida folk-tales access to the upper regions is gained by an arrow rope constructed, as here, by shooting one arrow into the notch of another (see Second Report of the Committee under the writer's notes on the Haida Beliefs, &c.).

upon a couple of men paddling about in a canoe. One, whose name was *Tᴇ'ltcapsum* (duck), sat in the bow, and the other who was called *Ela's* (sea-cucumber) in the stern, he being the captain. Said Qais to them: 'Where are you going?' Tᴇ'ltcapsum replies, 'We are out trapping,' and becomes so frightened that he immediately dives into the sea. Qais now takes the bait the pair were using, and when Tᴇ'ltcapsum comes to the surface some little way off throws it at him and strikes him on the head with it. Where it struck a white spot immediately appeared. Tᴇ'ltcapsum looked round to see what had happened, and Qais throws a second piece at him, and hits him this time on the nose. Again a white spot appeared. The duck now takes to flight, crying out in fear as he goes '*anin, nin, nin, nin.*' Ela's observing Qais's action now also takes to the water and dives down to the bottom and remains there. Qais seeing this calls out to him, 'Very well, my friend, if you want to stay down there do,' and therewith he transforms him into a sea-cucumber (Holothurian). Thus originated the white-headed duck and the sea-cucumber.

After these events they went up towards the head of the Sk·qo'mic River. On their way they perceive a village and three Fort Douglas men (members of the Stlatlumʜ tribe, whose territory is contiguous to that of the Upper Sk·qō'mic), who are 'packing' something on their backs. Qais transforms these men and their packs into three big boulders which are to be seen at this village to this day. Going on from thence they come to a mountain, down the slope of which they perceive *Skōā'watc* (sturgeon) coming. Him also they change into stone. A little after, as they still journeyed on, they come upon *K·winī's* (whale), and he too is transformed by them into a rock. In course of time they arrived at the spot where the village of *'nku'k·ᴇpenatc* now stands. There they saw two men in their canoes. These, both men and canoes, they turn into stone; hence the name *n'ku'k·ᴇpenatc*, which signifies the place of the stone canoes. Some time after this they meet a man carrying a spear. They request him to give them his weapon, but he refuses to do so, and him they likewise turn into stone, where he may be seen to this day with his spear in his hand. At this point my informant's memory gave out, and he could tell me no more of the doings and transformations of the Qais.

Tsai'anūk.

There was once a man who was the father of twins. One night he dreamt a strange dream. In his dream he was bidden to collect the bones of all the fish that frequented the Sk·qō'mic River. He was to place them in a box divided by partitions, a pattern of which was shown him in his dream. The bones of each kind of fish were to be kept separate in the divisions of the box. On awaking he set about his task. When the box was ready he filled each division of it with the bones of different kinds of fish, and then placed the box in a large hole of a living tree, whose trunk he had hollowed out for the purpose. He then covered up the aperture so that the box could not be seen. Shortly after this he died, and from that time onward no fish came into the river. Many years later a man chanced to pass by the tree in which the box of fish-bones was hidden. When he approached the tree, his senses were taken from him, and he wandered round and round the place in a kind of trance. In this state he was shown the box hidden in the tree, and

instructed what to do with it and its contents. When he came out of his trance, he cut away the bark which had grown over the hole completely and took out the box and opened it. The various divisions of the box no longer contained bones, but only a little dust. Some of this dust got on his hands and fingers, and he took some moss and went down to the river and washed his hands in the water with the moss. As he washed a gale of wind arose, and little fish darted out from the moss in hundreds. He now put the box back into the hole in the tree again and went home. It was evening when he arrived, and his wife, who had been alarmed at his long absence, asked him where he had been all day. Not desiring to tell her yet of his strange adventure he said that he had gone to the river and had fallen asleep on the bank. Early next morning he goes down to the river where he had left the moss, and where the little fish had so suddenly appeared, and found to his great joy that the waters were teeming with fish, amongst which was a new kind afterwards called *tsai'anūk*. It would seem that the people had been aware of the reason of the disappearance of the fish from the river, and had a tradition among them that they would return again some day when the dust of the bones, which had been hidden away by the father of the twins, should be found and placed in the water. The man now saw from the quantity of the fish in the river that he had truly brought back the fish, and ran home and told his wife. From that time on the people of this village had plenty of fish, which aroused the jealousy of the other villagers, and one day the box containing the bone dust was stolen by some one and taken to another village. This brought about the death of the man who had first found the box, for on its being taken from the tree a gale arose which overwhelmed his canoe and drowned him. From that time the people on the river every year put a little of the bone dust in the water and never lacked fish again.

I was unable to identify the *tsai'anūk*. They are a kind of small fish like smelts or oolicans, but differ from these in that they are never found floating dead on the water, and they come and go in a mysterious manner. The Sk·qō'mic always regarded them as the descendants of the twins. Twins, according to the beliefs of the Sk·qō'mic, had power over the wind; hence the rising of the wind when the bone dust was disturbed. If any one ate tsai'anūk and *swī'was* (oolicans) at the same meal he would drop dead, the Sk·qō'mic believed.

Te Mᴇn-tlᴇ-Saiē'lᴇm.
(The Son of the Bright Day.)

Long time ago a shaman named Tculq had two daughters. One fine day the two girls got in their canoe and went out on the water. When they were some distance from the shore they ceased paddling and lay down in the canoe one at each end. They then began to sing. Their song was addressed to a certain mysterious youth who was supposed to live at the bottom of the water. The words of the song which they repeated many times were as follows :—

Atcinā' ! Atcinī' ! Atcinā' ! Kwi'nā yatcsī its tᴇm
Kwinā'-sī-ā'lī - - - i,

which, freely translated, may be rendered as follows :—'O dear ! O my ! We have been told that a handsome young man lies below ! Oh that he would come up !'

When they had been singing a little while they saw a form rising

through the water. It was young AiEt (black cod). Said the girls to him when he came to the surface: 'We don't want a man like you with big bulging eyes. You can go back again.' They sang again, and presently Tsăcilē'uk (rock-cod) came up. As soon as they perceived him they derided him, saying: 'Do you think we want a man like you? Go down again, you big-mouthed creature.' Rock-cod, much mortified at their treatment of him, sank slowly to the bottom again as they continued their song. Presently they perceived a bright and fiery form rising to the surface. The waters glowed as if a great fire burnt beneath. 'This must be he,' said one to the other. But when this glowing body rose to the surface they saw it was only Tūk·to'q (red cod). The girls are angry and disappointed as he appears, and revile poor Tūk·to'q bitterly. 'You big-eyed, gaping-mouthed, short-waisted, ugly creature, get out of our sight and don't come here deceiving us again.' Tūk·to'q sank slowly to the bottom again.

And thus it was with one fish after the other that came to the surface at their singing: each and every one the girls dismissed with scornful, abusive words. At last came Kōs, the prince of fishes (spring salmon), but he fared no better than the rest. When they saw his graceful silvery form come shooting through the water they cried out to each other: 'This must be he. How bright and shining he is!' But when he got close to the canoe they perceived that they had been mistaken. 'We don't want you, Kōs,' cried they. 'You have a black mouth. We don't like black-mouthed men. Go away and hide your black mouth.' They continue their singing as Kōs disappears. Presently they see an arrow (*s'mā'al*) come shooting up out of the water. As it falls back they paddle towards it, each eager to seize it first. The younger of the sisters grasps it first. They now sing again, and a little later a second arrow shoots up as before. This time the elder sister is the first to get it. Then a third appears in the same manner, and after that a fourth. Each sister succeeds in getting one of these, so that they now have two arrows apiece. They sing their song again, and presently a bow (*tō'qōatc*) and quiver (*tciau'q*) are thrust up. These the younger of the two manages to secure first. Once again they repeat their song, and a few moments later they behold a golden form, bright and shining like the sun, coming up from the lower depths. This at last is he whom they desired. He is *MEn-tlE-Saiē'lEm* (Son of the Bright Day). They paddle towards him, and when the canoe has approached near enough he springs into the centre of it. He looks from one sister to the other to see which possesses most of his property. Perceiving that the younger sister had most, he goes to her end of the canoe and sits down by her side, and the girls then paddle back to their landing. When they arrive the elder sister, who is greatly disappointed and jealous of the other, springs out first and runs to her father complaining that her sister has taken her *sī'ya* (lover) from her. TculQ smiled and told her not to distress herself, that neither of them would have him long. It would appear that TculQ used his two daughters as decoys to attract young men to his house, where he wickedly destroyed them in various ways by his shamanistic powers. The younger daughter being well aware of this takes advantage of her sister's absence to warn her lover of what awaited him at her father's hands. Said she to him as they were approaching her father's dwelling: 'Take care of yourself when you pass through the door. My father has a magic door that closes with a spring upon people as they enter, and cuts them in two if they are

not wary. He has killed a great many of our lovers that way. When we get to the door watch how I get through, and follow in the same manner. If you succeed in getting through safely you must not, however, think you are free from danger. Another danger awaits you. My father will spread a fine handsome bear skin rug on the ground for you to sit upon. In the hair of this skin are fixed many sharp claws of the grisly bear (tlatla'lEm) so skilfully hidden that no one would suspect their presence. Should any one, however, be unwary enough to throw himself down on the skin, these claws will tear and rip him to pieces. Be careful of yourself, therefore, when my father invites you to sit down on this rug and avoid the claws.' MEn-tlE-Saiē'lEm thanks the maiden for her warning, but tells her not to fear for him; that his medicine is stronger than her father's. Before entering the house MEn-tlE-Saiē'lEm filled his clothes with pieces of rock and stones. When they got to the door the girl gave a sudden leap and passed safely through. MEn-tlE Saiē'lEm, observing her action, did the same, and passed through without harm to himself; but the door springing to after him caught the end of his quiver as it trailed in the air and cut off the end of it. The shaman looked up and accosted the youth thus: 'Ah! *stūta'tl* (prospective son-in-law), you have arrived, have you? Come and sit down on this rug.' And with that he shakes out a fine bearskin and spreads it on the floor. MEn-tlE-Saiē'lEm throws himself on the skin, as if he had no suspicion of its hidden dangers, and rolls about upon it as if he sought to find the most comfortable position, breaking off as he did so all the points of the sharp claws with the stones he had placed inside his garments. He was thus able to lie upon the rug without harm. They talk together for a while, and then, as night had come on, they retire to rest, MEn-tlE-Saiē'lEm and his bride occupying the same bed. Before they rose next morning she warns him that a third trial awaits him. 'In the yard yonder,' said she, 'my father has a big canoe he is in the course of making (*tcatwī'tl*). It is of rock and not of wood. In it is a deep crevice or fissure, down which my father will purposely drop his *Qohai't* (chisel) to-morrow morning and request you to dive in and bring it out. When any one does this the crevice closes over him and he is buried alive in the rock. I am greatly alarmed for your safety. Hitherto no one has escaped this trap of my father's.' The young wife is very sad and cries as she tells her husband of the danger ahead of him. MEn-tlE-Saiē'lEm bids her be of good cheer and not to be anxious for him. 'I shall do as your father desires me,' said he; 'his medicine cannot hurt me.' Presently the shaman calls out to the young man: 'Sāq (son-in-law), I want you to come and get my chisel for me; it has dropped down a deep crack in my *tcatwī'tl*. He got up at once, but before leaving his wife he requests from her some *stau'ōk·* (pipeclay)[1] which he hides upon his person. He now goes out to the old man, who points out to him the deep crevice into which his chisel has, as he declares, fallen. The young man takes a leap into the fissure, and as he enters he throws the *stau'ōk·* back over his shoulder, and the next moment the cleft closes over him. The shaman perceiving the *stau'ōk·* come from the rock imagines it to be his son-in-law's brains, which have been squeezed out by the pressure of the rocks upon his head as they closed upon him, and goes off laughing, saying as he went: 'I got him that time, sure.' Meanwhile

[1] Dr. G. M. Dawson obtained a specimen of this substance from the Sk·qō'mic on Burrard Inlet in 1875, and found it to be a diatomaceous earth, and not true pipeclay.

the youth finds himself in a kind of hollow or cave in the rock, on the floor of which he perceives a great number of human bones, the remains of the shaman's former victims.

Picking up the chisel he goes to the end of the cave, which opens to him, and he passed out with the tool in his hand. He hurries after the old man and overtakes him before he has reached the house. 'Sāq' (father-in-law), said he, 'here is the chisel you lost.' The shaman takes the chisel, laughs, and says: 'You beat me that time, son-in-law.' The night following this when the others had gone to rest the shaman, who possesses a little dog, calls the creature to him and holds converse with it in this wise: 'I am going to transform you into a *swā'kwil* (loon) and put you out on the water in the morning for my son-in-law to shoot at. You must take care to dive when you see his arrows coming, and each time you rise to the surface again come up farther off.' Mᴇn-tlᴇ-Saiē'lᴇm's wife was still anxious and troubled for her husband's safety. Said she to him: 'None of our young men ever escaped from the rock-trap before, so I do not know what mischief my father is plotting against you now. I feel sure he will not desist from his attempts to kill you, and I am fearful of what may befall you.' Mᴇn-tlᴇ-Saiē'lᴇm comforts her by assuring her that her father cannot really harm him, do what he will. Early next morning the shaman takes the dog to the beach and, muttering magic words over it, transforms (*siūwēn*) it into a loon, which enters the water near the shore and begins to swim and dive about just in front of the old man's landing. He now returns to the house and bids his daughter wake her husband and ask him to go to the beach and shoot a loon which is sporting about there close to the shore. Mᴇn-tlᴇ-Saiē'lᴇm gets up and goes to the beach, taking his bow and arrows with him. His arrows have the faculty of striking and killing whatever he shoots them at. He takes aim at the loon and shoots. The seeming bird dives as the arrow reaches it. To the young man's surprise the loon is not killed, only wounded, the arrow merely breaking its flesh and passing on beyond. The youth asks his wife to get him a second arrow. The loon having come to the surface again, though farther off, he shoots the second arrow at it, but meets with no better success than before, merely wounding the bird without killing it. He asks for a third and yet a fourth arrow, but the loon is still alive and passing out of sight. Perceiving now that his father-in-law was working his medicine against him, and having shot away all his arrows, he adopts another plan. Said he to his wife: 'Has your father got a *sçum*?' (big cedar pot or kettle). 'Yes,' replied she. 'Fetch it for me and bring it down here to the beach. I will go after the loon in it.' She did as he bade her, and he set out after the wounded loon in the tub. He took his bow with him, and as he passed his arrows which were floating on the surface he picked them up. He now shot them at the loon again, but with the same result as before. He could only wound the loon, which swam farther out at each shot. The old shaman had watched the proceedings thus far without saying a word or doing anything. As the loon and his son-in-law pass from their gaze he stands up and takes his bearskin garment, shakes it, and turns it several times and then puts it on again. Consequent upon this action there arose forthwith a great storm, and the wind caused the waves to rise mountain high. The young wife is greatly distressed thereat, and believes that she will never see her husband again. She continues for a while to gaze seaward, but nothing but the mountainous billows meets her eyes, and presently she seeks the

shelter of the house, believing Men-tle-Saiē'lem to have been overwhelmed by the waves. In the meantime the latter pursues and presently comes up with the loon. This time he succeeds in killing it. As it expired it barked like a dog. 'Ah!' said Men-tle-Saiē'lem, 'now I understand why I could not kill you before. Very well, you shall serve my purpose now.' By this time the storm has reached him, but he is in no wise alarmed at it. He commences to sing, and the tempest at once subsides immediately about him. Within a certain radius the water is as calm as a sheltered pond. As soon as he had secured the dog-loon he makes for home again. On his way he kills a great number of ducks which the storm had driven shorewards. He shoots so many that they overfill his boat. He utters *sīūwē'n* words over them and they shrink at once to a small compass. He then fills the canoe again, after which he makes directly for the shaman's landing-place. The tempest is still raging all about him on every hand as before. When he reaches the shore he finds it deserted. Everybody is indoors, having given him up for lost. He enters the house, and when his wife perceives him she is overjoyed at his return. He tells her he has killed the loon her father wanted and bids her go to the sçum and bring it up and cook it for her father. She goes down to the landing and takes up from the bottom of the tub what appeared to her to be a single bird. But when she held it in her hand another appeared in its place. She picks up this also only to find the same thing occur again and again. Presently her arms are full, and yet a bird remained in the bottom of the tub. She goes to the house and tells her husband. 'Take your big basket,' said he, 'and pack them up on your back.' She does so, and when at last she has exhausted the supply the house is half full of ducks. Men-tle-Saiē'lem now utters *sīūwē'n* words over them again, and they are reduced to apparently a few only. These he takes and plucks and afterwards roasts them. In plucking the loon he said to it: 'When your master takes you up to eat you I want you to bark like a dog.' When the birds were cooked Men-tle-Saiē'lem made a cedar dish and placed them upon it and laid it before the shaman, who began at once to partake of them. When he commenced he thought he could easily clear the dish, but as soon as he has eaten one, another appears in its place. Presently he takes up the loon, and as he was eating it, it barked like a dog, and the old man knew at once that his son-in-law had outwitted him again. Said he to Men-tle-Saiē'lem: 'You have beaten me again, son-in-law.' In his greediness the shaman had overeaten himself and now became very ill. Early next morning he calls out to his daughter to come to him. 'I am very sick,' said he, 'and I want your husband to go into the woods and gather some *yit-twā'n* (salmon-berries, *Rubus sp.*) for me.' Now it was winter time, and not even a green leaf could be found, much less fruit. The daughter tells her husband what her father had requested him to do. At first he would not get up, but lay and thought out a plan of action. This time his patience was exhausted, and he determined to punish his wicked, selfish father-in-law. When he had thought out his plan he got up and requested his wife to get him some *slō'wi* (finely beaten inner bark of the cedar, *Thuya gigantea*). She gives him some. As he leaves her he tells her not to be alarmed. 'I am likely to be delayed in my quest,' said he. 'What your father desires is not easy of accomplishment at this season of the year.' He directs his steps towards the forest and pushes his way through the thick underbush till he arrives at the foot of a mountain.

Here he comes to an open glade (*swā'wᴇk*) where many *yit-twā'nai* (salmon-berry bushes) are growing. He halts here, procures some bark of the *klō'lai* or alder tree (*Alnus rubra*), and chewing this blows the juice from his mouth upon his wad of *slō'wi*, thus dyeing it red. But only the outer bark is stained red, the inner remaining yellow. He now proceeds to tie little tufts of it to the salmon-berry bushes, some of the tufts being red and some yellow. Next he transforms these tufts of *slō'wi* into salmon-berries, some of which are red and some yellow. This originated the salmon-berry, and thus it is that the fruit of one bush is red and that of another yellow. But the fruit was not yet ripe. To ripen it he needs some assistance. So he next proceeds to call upon some of his ancestors to help him. He invokes them in the following terms: 'Come to me, my grandparents, and help me ripen this fruit!' The grandparents whom he calls upon for this purpose are the *titc-titcᴇnīs*, or humming-bird (*Trochilus sp.*), the *S'k·ukumkum*, or humble-bee (*Bombus sp.*), and the *Qit*,[1] or wren (*Troglodytes hiemalis?*). The two former were males, the latter a female. The bumble-bee is the first to respond to the invocation. He buzzes round and round in the air in lessening circles until he alights upon the salmon-berry bushes. He is followed by the humming-bird, and he again by the wren. They all three set to work at once to ripen the berries. He begs them not to loiter over their work, as he wants the berries in four days at the latest. When the fourth day arrived all the berries were ripe and ready for picking. He had brought a small woven basket (lēalēuk·) with him. This he soon filled, putting into it only red berries. When it was full he uttered *sīūwē'n* words over it, and the berries immediately sank down, leaving room for more to be added. When it was full the second time he put it aside and makes another little receptacle from alder-bark (pīā'kō). This he fills in the same way with the yellow berries. When full he sprinkles over the fruit some of the needles of the hemlock-spruce. As he does so he converses with the needles and instructs them in this wise: 'Some of you must stick to the berries, and when my father-in-law eats them you must stay in his throat and not let him swallow you or spit you out. You must then begin to grow, and go on growing till you come out through the top of his head.' On the red berries he sprinkles no leaves, intending these for his wife and sister-in-law.

He now starts homeward after thanking his grandparents for the help they had given him. He has not picked all the berries that were ripened, and as he leaves he bids them enjoy what is left themselves. On the afternoon of the fifth day he arrives home with his two baskets of berries. He calls to his wife and says: 'Has your father any cedar-plates (*Qāpīyoitl*)?' The wife answers that he has, and brings him one. On this he now pours out the yellow berries, some of which have the little needles of the spruce still sticking to them. The basket of red berries he gave to his wife and sister-in-law. He then presents the dish of yellow berries to his father-in-law, saying as he does so, 'Here, Sāq, are the berries you desired: they have cost me some trouble to procure for you.' The old shaman grumbled when he saw how few they seemed.

[1] It is interesting to note that a myth of the Haida (Queen Charlotte Islanders) makes the wren, called also by them *Qit* or *Whit*, the ripener of the wild berries. She is invoked among them in a song the words of which I have given in the original with a free translation in my notes on *Haida Stories and Beliefs* (see Second Report of the Ethnological Survey of Canada, 1898).

'I could eat twice that quantity,' said he. But to his surprise he finds the fruit more than he can consume. Eat as many as he will, some still remain on the platter. Presently he begins to cough and spit. Some of the spruce needles have got into his throat and he cannot dislodge them. Between his spasms of coughing he cries out: 'Ah! son-in-law, you have beaten me this time.' Saying this his eye (for it seems he possessed but one) begins to start from his head, and presently a young hemlock-spruce burst through his crown and speedily grew into a big tree. MEn-tlE-Saiē'lEm then called his wife and sister-in-law, and said to them: 'We will go away and leave your wicked father now.' They forthwith pack up their belongings and start off. When they get outside of the house MEn-tlE-Saiē'lEm gives a great kick to the back of it, and the whole structure falls in and is transformed into a big rock with the tree that grew from the old shaman's head still standing up, and apparently growing out of it.

This boulder, which the Indians used to look upon as an enchanted rock, is said to be situated near Nanaimo. Even now the older Indians believe that the shaman is still shut up in it. They declare they can sometimes hear him saying, 'You have beaten me this time, son-in-law,' and if any one passing by on the water were to revile it, or call it opprobrious names, such as 'old one-eye,' they believe a tempest similar to that the old shaman brought upon MEn-tlE-Saiē'lEm when he went after the loon would immediately arise and drown all in the canoe.

From the fact that this rock is situated within the borders of the SnamaimuQ, as well as from the hero's name being doubtful Sk·qō'mic, it is pretty certain this story has been borrowed from the SnamaimuQ.

TE Qoitcītā'l, the Serpent-slayer.

A long time ago many people lived at Stāmis, a village at the mouth of the Sk·qō'mic River. The son of the chief had just been married. The night following the marriage, just before daybreak, the old people heard the cry of *TE Sīno'tlkai* (a huge double-headed water-serpent) as he passed from one side of the mountain to the other. The old people woke up the young couple who were sleeping together by throwing cold water over them, and told the young man that he ought to get up and go after the Sīno'tlkai. The youth was deeply offended at this treatment on his wedding night, and would not at first stir; but presently he said to his wife, 'I will do what they wish. I will follow the Sīno'tlkai and kill it. Don't be alarmed during my absence. I shall be away only four days.' He was really absent four years, though the years seemed to him as days. So he got up and took his bow and arrows and blanket and went after the serpent. When he came upon the creature's trail the stench which it had left behind it in its passage was so terrible, and the buzzing of the flies which the smell had attracted so annoying, that he was obliged to keep some distance off. From time to time as he went along he bathed himself. After a while he came upon the serpent, which was lying lengthwise across a small lake. Its heads rose up on one side, and its tail on the other. Qoitcītā'l would not bathe in this lake where the serpent lay, but sought out another spot a little way off. The serpent stayed here testing the lake's capacity for the space of two whole days as it seemed to Qoitcītā'l. In reality a whole year thus passed away. It then went on again followed by Qoitcītā'l as before, who bathed

himself frequently as he went along. They came to several other small lakes, all of which the serpent tried as before, but none of them was big enough for its purpose. Thus the third year passed, which to Qoitcītā'l seemed as another day. At last the serpent came to a lake large enough for it to swim about in. Into this the Sīno'tlkai dived. On the edge of the lake Qoitcītā'l built himself a house and watched the serpent which from time to time came to the surface of the water to disport itself. One night Qoitcītā'l dreamt that he killed the serpent with a big heavy spear made of resinous pine-wood. In his dream he seemed to be in a large canoe, and he possessed two of these heavy spears. So when he awoke he built himself a canoe, and made a couple of spears after the fashion of those he had seen in his dream. When he had finished his canoe he launched it on the lake. The serpent was not visible at the time, so he allowed the canoe to drift about as it would. By-and-by the serpent came to the surface again at some little distance from Qoitcītā'l. He at once paddled quietly towards it. The serpent's two large heads were now raised in the air with its great mouths agape. When it opened its mouths it was like the opening of two fiery ovens; and the cries it made on these occasions were exceedingly terrifying. Qoitcītā'l paddled towards the nearest of the heads and struck it just at the junction of the neck with one of his spears which remained sticking in it. He then hastily paddled towards the other and did the same with it, and the serpent sank to the bottom of the lake. Qoitcītā'l thereupon went into a trance and remained in that condition for some time. While he was in this state the water of the lake rose up and carried him to the top of a high mountain. When he came out of his trance, in which he had learnt many secrets and much strange knowledge, he looked intently at the water which immediately began to sink, and in a little while the whole lake was dry. He now descended the mountain and got down to the bed of the lake across which he perceived, stretching from side to side, the trail of the serpent's bones. These were now clean and free from flesh, and some of them were curiously shaped. Some had the form of swords, and some of blanket-pins or brooches. He took possession of two of these—one of the sword kind and one of the brooch kind—and returned to his house on the edge of the lake. Having now accomplished his task he determined to return home. He accordingly sets his face homewards. To get home he had first to pass over many mountains and rivers. One day he perceived a flock of mountain-sheep on a ridge before him. Thereupon he takes his new sword, which possessed magic properties, and waves it in the air, and all the sheep straightway fall down dead. He now skins them all, and dries their hides. When they are dried he packs them up and takes them with him. There are many hundreds of them, but his magic enables him to carry them all easily. As he journeyed on he came to a certain mountain which it was necessary for him to cross But his passage over this was hindered by the presence of a huge snail which barred his way whenever he sought to cross it. He tried every means to pass this creature, but always failed. At last it occurred to him to use the Sīno'tlkai-bone brooch, which like the sword possessed magic properties. He now points this at the snail, and it immediately shrivels up like a green leaf in the fire, and dies. At last after much travelling he comes to the head of the Sk·qō'mic River, at the mouth of which his own village is situated. Between the head and the mouth of the river there are many *ō'kwumūq*,

or villages, which he has to pass on his way. The first village was on the side of the river opposite to his own. When he got over against it he covered himself with a white blanket and sat down to rest and await events. The people of the village soon perceive him and cry out to one another wondering what the strange white object is. Said one to the other, 'Let us go and see what this white thing is on the other side of the river.' They all come down to the river's edge. Qoitcītā'l now stands up and waves his magic sword in the air, and all the people shrivel up as the snail had done, and fall down dead. He now crossed over the river and took a *Qok·ō'lstEn*, or large basket used for gathering herbs, and filled this with the leaves of certain plants and herbs. He then broke these up and bruised them, and made therefrom some powerful medicine the magic properties of which he had learned in his trance. With this he sprinkles all the dead, and they are immediately restored to life again. After this the people take a number of canoes and construct from them a large raft. On this they place Qoitcītā'l and present him with a great number of blankets. They also give him one of the girls of the village for a wife. Qoitcītā'l accompanied by some of the people of the village now goes down the river. At every village they come to Qoitcītā'l kills all the inhabitants by waving his sword as he had done at the first place, and afterwards restores them to life. At each stopping-place he is presented with many gifts, and a girl for wife, and some of the people accompany him; so that by the time he has reached his own village the raft is loaded with people and presents, and he possesses nearly two score wives.[1] When he arrived at Stā'mis he does the same there as at all the other places and kills everybody, his own parents and first wife included. Then he brings them all back again to life except his wife. He does this to impress the people with his power. His wife had taken another husband, and so to punish her for her want of trust in him he would not restore her to life. He now takes all his new wives and presents into his father's big house. A great feast is then held and all the visitors are generously entertained for many days. There was no scarcity of food or game, for Qoitcītā'l had only to go into the woods and wave his magic sword before him and everything immediately fell dead at his feet. From this time on Qoitcītā'l became a great man and the chief of his *ō'kwumūq*.

TE Sqōqwā'otl, or the Deserted Youth.

A youth was once undergoing his *k·waiyā'sōt*, or training for medicine-man. He had led an isolated life in the forest, according to the custom of novices, for some time, and had eaten no food for several days. Now it happened that just at this time there was a scarcity of food in the village to which he belonged, and a party of girls had gone into the woods to dig *Sqōtluk·* (*Pteris aquilina*) for food for themselves. They had secured some roots and had roasted and eaten them in the woods, throwing aside the hard cores.[2]

As the youth was wandering round in the woods he came upon the

[1] Wives acquired in this way are called by a special name to distinguish them from those obtained in the ordinary manner. This term is *Āmitlā'ntEm*, and means 'presented' or 'freely given.'

[2] The edible part of this root when roasted, my informant stated, is very like in substance and appearance the flesh or meat of the cocoa-nut. The outer part only is eaten, the inner part being a hard core, which is thrown aside. In times of

spot where the girls had roasted their fern-roots. All around him lay the discarded cores. The sight of these was too much for the young man's hungry stomach, and he sought to appease his cravings for food by gnawing at some of them. This occurred towards the end of his training. When he had completed his *k·waiyā'sōt* he returned to the village. Now when the elders of the village learnt that the girls had been in the woods roasting Sqō'tluk· near where the youth was undergoing his training it entered their minds that he might break his fast upon the remains of their meal. So when he returned home his parents undertook to test him. They did this by drawing scarifying knives all over his body. In the process one of the fern-root cores was drawn out of his flesh, at sight of which his father was shocked and scandalised. He informs the people of his discovery, telling them he is greatly ashamed and grieved at his son's wicked deception. It is decided that he must go back to the woods and go through the whole procedure from beginning to end over again. So he returns to the training-ground and enters upon a second course of fasting and exercise. No one expresses any sorrow for the youth except his old grandmother, who cries when she learns that he is sent back in disgrace to repeat his trying ordeal once more. Among the personal belongings of the young man was a little dog which was much attached to him. This dog the old grandmother called to her side one day, and told it that the people had determined to go away from the village and abandon her grandson, who had disgraced them by breaking his fast during his k·waiyā'sōt. 'When your master returns,' said she to the dog, 'he will find the village deserted and all the fires out. I am very sorry for him and want to help him all I can. I intend to keep all the cores of my Sqō'tluk and make them into charcoal and bury it in a big clam-shell, and when my grandson returns you can tell him where to find it, so that he will not be without fire.[1] You must stay behind when the people go, and wait for your master and do as I instruct you. When I have buried it I will show you the spot.'

It was as the old woman had told the dog. The whole village felt that they could not harbour a youth who had brought such shame upon them, and so, at the suggestion of Sk·auk·, the Raven, they determined to go away to another camp and leave the youth to his own resources. To make their desertion of him the more complete and exemplary, when they are ready to start they take water and pour it upon all the fires and so put them dead out. Just before they did this the old grandmother, unobserved by any one, converted her fern-root cores into charcoal and buried it in a clam-shell near one of the posts of the dwelling, and bade the dog, which was observing her, remember where to bid his master look for it. They all now go away, taking their belongings with them, the little dog alone remaining behind. Some time afterwards the youth, having completed his course of training, returns once more to his home. When he perceives the abandoned state of the village he quickly comprehends what has happened, and walks up and down, crying, feeling heart-broken at their desertion of him. His little dog tried again and again to attract his

scarcity and famine the Indians had frequent recourse to these roots, and dug up and ate large quantities of them, the old people and children having little else indeed to subsist upon.

[1] It would appear from the precaution here taken by the old grandmother that the preservation of fire was a matter of supreme importance in the early days of the tribe, and the procuring of it afresh a task of much difficulty and trouble.

attention and lead him to the spot where the buried cores were smouldering in the clam-shell; but for a long time his master would take no notice of him. Presently, when his grief had somewhat subsided, the importunity of the dog and its unusual behaviour aroused his attention. For the dog, on perceiving that it had at length attracted its master's notice, had run to the foot of the post where the fire was secreted and begun vigorously scratching there, looking up at its master the while and barking excitedly. Said the youth to himself: 'I believe my grandmother has buried something there for me.' He then went to the spot and speedily discovered the hidden charcoal, with which he soon made himself a big fire. He now made a bow and some arrows for himself, and shot many small birds and chipmunks (*Tamias striatus*), and from the skin of these, when dry, he made himself a garment to cover his nakedness.[1] After this he makes a big box in front of the house, in which he sits and looks about him.

One morning just about sunrise he is sitting with his gay robe wrapped about him, when he perceives the Sun coming down to him. When his visitor got near he said to Sqōqwā'otl: 'That's a fine coat you have on. I would like to make an exchange with you. My garment has magic qualities, and whoever wears it need never want for food.' 'All right,' said the youth, 'I'll exchange with you. I am badly in want of a coat of that kind just now.' The exchange is forthwith made, and each puts on the other's garment. Then, said the Sun to the youth, 'If you dip one corner of my cloak in the water when you want something to eat, you will always be able to obtain any amount of *slau'it* (herrings). Be careful not to dip too much of the garment in, or the fish will choke the stream.' After this the Sun returned to his own country, carrying with him the youth's cloak. On the morrow Sqōqwā'otl goes down to the water to try the 'medicine' of his new garment. He dips one corner in as the Sun had instructed him, and immediately the water swarmed with fine fat herrings. He straightway makes a *tli'tamen*—a kind of rake, on the spikes of which the fish are impaled as it is drawn through the water. With this he catches great quantities of the fish, after which he threads them on strings and hangs them up to dry. He continues at his task till he has filled his father's house with them. In like manner he then proceeds to fill the houses of all the others in the village except *Sk·auk·* the Raven's. He had become aware by some means that the proposition to desert him originated with the Raven, so he would not give him any herrings. On the contrary, he filled his house with the stinking, rotting entrails of the fish he had cleaned, by way of taking his revenge upon him. When he had stocked all the houses with dried herrings, *K·lā'k·a*, the Crow, paid a visit to the village one day, and, being hungry, soon discovered the entrails of the herrings and began eating them. When Sqōqwā'otl perceived the Crow, he asked him if he knew where the people of his village had settled, and whether he had seen his grandmother. , Yes,' answered the Crow, 'I know where your people went. They are living on the other side of the water, and every day I hear your grandmother crying for you.' 'Ah!' said the youth, 'I am sorry for my grandmother, and I want you to take these four herrings and give them to her, when she is outside and nobody is looking, and tell her to come over here, where there is now plenty of food. I know they haven't much over

[1] During his k·waiyā'sōt the novice must wear no clothes. He must go entirely naked the whole time.

there.' The Crow undertook to do as the youth requested, and started off on his mission. He finds the old woman sitting in the bow of a canoe crying to herself. He alights on the edge of the canoe and cries out to her in the following words : '*K'āq, k·āq, tᴇ tcatcᴇlā'tltᴇn tᴇ um-mun-mats, kāq'* [1]—'Plenty, plenty food where your grandson is, plenty.' He then disgorges the four herrings which he had carried in his gullet. The old woman quickly comprehends the message her grandson had sent by the Crow, secretes the fish on her person, and goes home. At night, when all were abed and, as she supposed, asleep, the old woman approached the fire and in the shadow of the big night log [2] produced the herrings and began to roast them over the embers. She thought that no one would observe her at this time ; but it so happened that one of the children woke up and saw her. The child lay near the father's head, which was raised some little distance from the bed by the head-rest, thus leaving a space between his neck and the bed. Looking through this space, the child observed the grandmother cooking and eating her herrings. She presently roused her father and told him what the old woman was doing. The savoury smell had by this time filled the whole building and aroused everybody. The father demands from the old woman how she came by the herrings she had been stealthily cooking. At first she made no reply, and he had to ask her the same question three times before she would respond. She then told him that the fish came from her deserted grandson, and that the Crow had brought them to her that afternoon with the message that there were plenty more at the old village. On the following morning the chief calls all the people together and tells them of the herring incident, and that his son whom they had deserted was living at the old village in plenty. He proposes that they shall all return thither, as food is scarce in their present quarters. It was agreed that they all return. So they started off for their old *ō'kwumūq* in their canoes and in due time arrived at the landing-places. They came in single file, one canoe behind another. As they drew near the shore, the youth donned his wonder-working cloak. To those approaching he now had the glorious, resplendent appearance of the noonday sun. They could not look upon him as he sat in front of his dwelling for the dazzling splendour of his garment. Before they landed, those who had *kᴇmkā'mai* (daughters) dressed them in their best and gayest blankets, for the purpose of presenting them to the youth as wives. Among these was Raven, who had two daughters. These he not only dressed in their best blankets, but also painted their foreheads. Presently, when all were ready, they landed, and the chief led forward his daughter and offered her to the young Shaman as his wife. The others in turn did likewise, Raven among the rest. He accepts all but Raven's daughters. These he scornfully rejects, and tells Raven to keep them, that he doesn't want them, and will have nothing to do with them. He then bade the people go to their old dwellings and they would find plenty of food awaiting them there. His many wives he takes to his own house. When Raven and his rejected daughters arrive at their home

[1] This is not good Sk·qō'mic. The crow is supposed to have mangled it somewhat. In correct Sk·qō'mic the expression would be thus rendered: *K·āq, k·āq, tᴇ stcaiē'tlᴇn tᴇ tlᴇs-nᴇ tᴇ ē'mats, k·āq*. It is possible that this story is not of Sk·qō'mic origin, hence the difference in the form of the expression. I called my informant's attention to this, but his explanation was that this was the crow's way of talking.

[2] The old Indians always banked up their fires, before retiring for the night, with one or more big logs. These kept the fire smouldering till morning.

they find it full of the stinking entrails of the fish with which Sqōqwâ'otl had filled their neighbours' dwellings. They are so hungry that they are fain to appease the cravings of their stomach by eating the fœtid mass. Thus did Sqōqwā'otl revenge himself upon Raven for his part in the people's desertion of him.

When everybody had once more assembled about his dwelling Sqōqwā'otl invites them to come down to the water's edge with him. Upon their arrival there he turns his cloak about and dips one corner of it into the water, and immediately the spot teems with fish. At first the people are too astonished to seize the fish, but presently they fill their canoes with them. From that time onward the people of this village never lacked for food, and Sqōqwā'otl's cloak brought him much honour and renown, and he became a great man among them.

SmEnā'tl, or the Story of the Chief's Daughter.

The chief of a certain large village once possessed a big dog. This dog was not a common dog. He was really a wizard, who had assumed this form for evil purposes of his own, though no one in the village was aware of the fact. One night he stole to the bed of the chief's daughter and ravished her in her sleep. When some little time had passed the girl found herself with child without any knowledge of the person who had brought this shame upon her. Suspecting that her ravisher would visit her again, she takes some red paint and mountain-sheep's tallow, and, mixing the two into a paste, smears the palms of her hands with it. Before she has discovered the author of her trouble her father perceives her condition and questions her concerning it. She is unable to give him any satisfactory explanation, and he is much grieved and ashamed. The following night the dog-wizard visits her again, but before he leaves her on this occasion she presses her paint-smeared hand upon his shoulders. In the morning, when all the young men of the tribe are engaged in their exercise on the village ground, she scrutinises their backs and shoulders to see if any of them bear the imprint of her hands in red paint. She passes them all in review before her, but cannot perceive the sign she is looking for on any of them. The evening of that same day the dog is lying before the fire, and the girl, wishing to occupy the dog's place, takes a stick and tries to drive it away. At first the dog will not stir, but eventually it consents to get up and move off. As it does so, she is greatly surprised to see marked upon its shoulders the imprint of a pair of hands in red paint. In her astonishment she cries out, 'Oh ! my father, I have discovered my ravisher. Look at the dog's shoulders ; it must be he.' The father looks at the dog and perceives the paint-marks upon his back. 'Very well, daughter,' said he ; 'if that is the father of your child you cannot live with me any longer.' Thereupon the chief goes some little distance from the village and builds his daughter a house apart by itself. When it is ready he sends her to live there. The chief is greatly ashamed ; and when later his daughter gives birth to twelve puppies he is so deeply mortified by the whole circumstance that he calls his people together and tells them that he wishes to go away out of sight and sound of his disgraced daughter and her unnatural offspring, and proposes a change of settlement. They agree to his plan, and presently all pack up their belongings, take their canoes, and paddle away to a near village. Near their old settlement is a point of land or promontory (*Sk·'utuks-En*, cf. radical for nose) stretching out some way into the water and hiding the

view beyond. They determine to settle beyond this point, where they will be out of sight of their old camp. In the meantime the poor deserted girl does the best she can in her lonely state for her strange family. Of the twelve puppies two only are females, all the rest are males. When they are old enough to run about the mother returns with them to her father's house in the abandoned village. One evening she split some pitch-wood for torches, and, lighting one of these, she went down to the beach to dig for clams. She had not long been engaged at her task when she heard sounds of singing and dancing coming from the village. She rushes back to see what it all means, and as she nears her own dwelling perceives the sounds to come from it. At the door one of the two young bitches is standing. When the latter sees her mother approaching she warns the others within the house, and the sounds at once cease. The mother's suspicions are, however, roused, and when she enters the house she asks them who had been singing. She gets no response to her question from the puppies, who are now speechless. She is sure, however, she had heard the sound of human voices, which indeed she had, for her progeny partook of the wizard-nature of their father, and had the power to throw off their dog-natures at will. This they had done in their mother's absence, and had sung and danced to the following words : 'Our mother thinks we are dogs, but we know better.' This they repeated many times. As soon as the sister who was watching informed them that their mother was returning they stopped their singing and dancing, put on their dog-skin coverings, which they had thrown aside for the occasion, and resumed the form and character of puppies once more. Hence when their mother questioned them they made no response. After looking round the place she returned to her work on the beach. This time she took a mat with her. When she got to the beach she stuck the torch in the mud and made to go on with her digging as before. Her intention was, however, to return to the house unobserved, and learn if possible the meaning of the dancing and singing she had heard before, and which now began again as soon as she had got to the beach. To this end she took her *skulq* (clam-digger) and, planting it firmly in the ground behind the flaming torch, hung upon it the mat she had brought for the purpose, thus shutting off the light from the village, and causing a line of shadow to appear between the beach and the house. Under cover of this she stealthily makes her way back to her dwelling. She sees one of the bitches standing in the doorway as before, but, being in the deep shadow of the mat, she herself is not seen by the watcher. She is thus able to get close to the building. She steals round behind it and peeps in through some chink in the wall, and is greatly astonished to see all her children, except the watcher at the door, in human guise, with their dog-raiment thrown aside. She enters suddenly from the rear,[1] and before they are aware of her presence, pounces upon their dog-garments and casts them into the fire, where they are quickly consumed. Thus she breaks the wizard's charm and overcomes his 'medicine,' and her children retain thereafter their human form. She now reproaches them for the deception they had practised upon her. 'It is entirely due to you and your dog disguises,' said she, 'that I have been deserted by all my people and left in my present forlorn condition.' They all listen in silence for

[1] As the old houses had but one door or means of ingress and egress, this entrance on the part of the mother from behind is not clear. My narrator was himself aware of this discrepancy, but was unable to explain it.

some time, and then the eldest boy says they are sorry for her and will now help her and make her happy and comfortable. 'O mother!' said he, 'I know what I will do for you: I will become a great hunter and kill lots of mountain-goats for you.' The second then chimes in 'O mother! I know what I will do: I will build you a nice house with carved posts' (*Stutūq*). The third then says, 'O mother! I will become a great fisher and catch lots of whales and seals, &c.' In like manner each declares in turn what he intends to do for her. The fourth would be a canoe-builder and build them all canoes. The fifth a bear-hunter and bring them many bear-skins. The sixth a song-maker and dancer and make songs and dances. The seventh a bird-hunter and bring home many birds. The eighth a transformer (sūīwē'n) and wonder-worker. The ninth would be a great chief and look after everything belonging to the village. The tenth would do a little of everything—in short, would become a 'Jack-of-all-trades.' The mother listened to them all without making any remark. The two girls now chimed in, and the elder declared that she would be a great basket-maker and make all kinds of baskets for her mother; and the younger, that she would be a berry and root gatherer and keep the house supplied with berries and roots. The day following they undertook the special task they had allotted themselves. The hunters brought home their different kinds of games and presented it to their mother, while each of the others presented her with some specimen of their craft or handiwork. From this time onward they lived in comfort and happiness. One day the mother, fearing they might on some occasion go round the point of land and come in contact with her former associates and friends, with whom she now desired to have no dealings, warned them never to go in that direction or they would get into trouble and danger. This caution served but to awaken their curiosity, and one day, when they were out on the water in their canoes, one of them remarked to the others, 'I believe that village round the point belongs to our mother's people; let us go round and see.' The others agreeing, they make for their grandfather's settlement. It was then early in the day, and in their canoes they had many seal which the fisher brother had caught that morning. When they had got round the point they perceived an old man sitting on the beach. They direct their canoes towards him and land close by. The old man observed their movements, but did not speak to them. Presently one of them accosts him in these words: 'We think our grandfather lives here and we have come over to see; can you tell us?' The old man then asks them where they come from. They tell him, from behind the point, where they live alone with their mother. The old man, who is really the chief, their grandfather, perceived at once that they must be his daughter's children who were born as puppies, and declares himself to them, telling them he is their grandfather whom they are seeking. They are glad to learn this, and present him with all the seals they had brought in their canoes. The old chief now calls some of his people and instructs them to unload the visitors' canoes and bring the seals up to his house. He is feeling very joyful and happy (tsā'stauq). 'Come into my house, grandchildren,' said he to his grandsons, 'and let me tell my people of your arrival.' They follow him into his big house, where the rest of the people soon assemble. The old man presently informs them that the strangers are his grandsons, the children of his deserted daughter, and proposes that they shall all go back to the old settlement. The idea is accepted, and he tells his grandsons that they

will return to the old village, and will arrive there with all their belongings early next morning. The young men then bid him good-bye, and set out to return to their mother to tell her the news. It is late in the day when they arrive, and their long and unusual absence has caused her much worry and anxiety. She has almost given them up for lost when they are seen approaching the landing. She questions them concerning their delay, and learns that they have visited her father and given him all their seals (*ā'suq*), and that he and all the rest are coming back to occupy their old quarters on the morrow. Next morning, while they are busy preparing to receive them, the son, who was a *sīūwē'n*, said to his mother: 'What will you do to the people to-morrow, mother? I know what I shall do to make them feel my power.' His mother made no reply, but, knowing her son's wonder-working abilities, she was curious to see what he would do. Presently the canoes were seen approaching the chief landing-place. When they were almost near enough to land, the *sīūwe'n* began to exercise his magic power, and caused a strong out-flowing current to take the canoes and carry them far out into the gulf and then bring them back again. This he did four times before he would allow them to land, and it was evening when they left their canoes. The sons now make their mother sit down in the foreground of the village on an elevated seat and pile up heaps of blankets by her side. The sixth son then opened the reception ceremonies with special songs and dances. In the first dance two bears appear—one a cinnamon (*k·tlalum*) and the other a black bear (*miaqutl*). This was a bear dance. These are followed by mountain-goats, after which all the brothers dance and sing together. The second brother, who was skilled in carving, danced in a mask of his own carving.[1] The visitors, who had remained in their canoes, looked on, and pronounced the entertainment a great success and the character-dancing very fine. After these performances are over the people land, bring up their belongings, and occupy their old quarters in the village. From this time onward they live together in amity, and the ten brothers are accorded by general consent the rank of chiefs.[2]

Story of SQēils, the Copper-man.

Once there were two brothers named Â'tsaian and Çukçuklakō's. Each one had six sons. All the sons were fine tall men except one. The youngest son of Çukçuklakō's was somewhat deformed, having a large protuberance on one side of his stomach. One day all twelve of the youths started off into the mountains. They climbed three successive

[1] The Sk·qomic used formerly, according to Chief James of Stāmis, to indulge in dramatic entertainments of the kind described in this story, which has apparently been evolved from the tribal consciousness to account for the origin of these particular masqueradings in which the participants appear under the guise of bears, mountain-goats, &c. I was not able to learn that the right to participate in these character-dances belonged to any particular family or gens.

[2] The bestowal of the rank of chiefs as a mark of honour and esteem upon the ten sons of the chief's daughter, as here related, bears out the statements of my informants on social customs—viz. that children of a chief's daughter take the rank of their father. Although their mother was a *smenā'tl* or 'princess,' they could not take her rank, as their father was of inferior birth. The conferring of this special privilege upon the wizard's sons shows us also, however, that men of inferior class, by possession and exercise of superior natural gifts, or by the performance of public services, could upon occasion be elevated by tribal consent to the rank of chiefs, as in the case of TE SQōqwā'otl, the hero of the story of that name.

mountains, and after they had passed the third they saw in the distance before them, on the brow of the opposite slope, a strange *ō'kwumuq* (village). As they stood regarding it and wondering what people lived there, they presently observed a man rolling a big copper ring down the mountain-slope opposite them, and, as soon as it had reached the bottom, drawing it back again with his breath. When they saw this beautiful ring, which glinted and shone in the sunlight, they determined to possess themselves of it. To this end they adopted the following plan: The eldest of Â'tsaian's sons was to go down into the valley to the spot where the ring stopped, and seize it when next it came down. The brother next to him was to follow after, but was not to go so far. All the rest were to do likewise, each being some little distance from the other, the deformed youth being last and consequently nearest home. They adopted this plan to make sure of securing the ring, being all quite well aware that its owner would not lightly part with it, and that the attempt might end disastrously for some of them. A little while after each had taken his place the ring came rolling down the hill again. As soon as it reached the bottom, the youth stationed there sprang out of his hiding-place and caught it up and immediately ran towards his next brother with it. As he ran he found himself impeded in his movements by the breath of the man who was pulling the ring back again, and he had great difficulty in getting along. The owner of the ring perceived that something had gone amiss with it, and came down to see what was the matter. He soon discovered the youth struggling off with his ring, and straightway made after him to recover his treasure. By this time the young man had reached the spot where his second brother was hiding, and just as the wizard was about to seize him he threw it to this brother, who immediately ran with it towards the next. Being fresh, this one made a good start, the more so as the wizard stopped to punish his brother by cutting out his heart. This he ate as the youth fell dead at his feet. He then started after the other, and came up to him just as he got to the next brother and passed the ring on to him. This one met the same fate as his elder brother, and likewise had his heart cut out and eaten. And thus it was with all of them except the last, who, as soon as he obtained possession of the ring, took the lump which caused his deformity from his side and threw it at the wizard. Thereupon a dense fog arose, and while his pursuer tried in vain to find him he hastened homewards, recrossed the three intervening mountains safely, and presently got near the village. As he approached, he called out to his father Çukçuklakō's and to his uncle Â'tsaian that all his brothers and cousins were killed. His father and uncle were in the house at the time, and when they heard him shouting they climbed up through the smoke-hole[1] to the roof to hear what it was he was saying. As soon as they understood the full import of his terrible news they threw themselves down into the fire to mark their deep grief,[2] whereupon their eyes shot out like fiery sparks and went, the right ones northwards, and the left ones southwards. Immediately upon this the

[1] This description seems to suggest a 'keekwilee-house' rather than the ordinary *lâm* of the Sk·qō'mic. Some of the upper Sk·qō'mic appear to have made use of the keekwilee-house, one of their villages being known by the term *Sk·umi'n*, which in Sk·qō'mic signifies a keekwilee-house.

[2] This practice would appear to have been unusual. I cannot recall that it has been recorded of any of our B.C. Indians before.

day became clear and fine. The youth now enters the house and relates his own and his brothers' and cousins' adventures, and displays the wonderful copper ring. Â'tsaian takes the ring from the lad, and says: 'I know what we will do with this hoop. I will hammer it down thin into a copper cloth for armour.' He therewith takes the ring and hammers it down till it is as thin as a piece of cloth. They now determine to go over the mountains to the strange village and have their revenge upon the wizard. Â'tsaian wraps the copper cloth[1] about his body and fastens upon his head a pair of mountain-sheep horns, and thus equipped they all three start out. They make for a cliff opposite the wizard's village. When they have reached this spot Çukçuklakō's and his son hide themselves, while Â'tsaian walks to and fro on the edge of the cliff on all-fours as if he were a mountain-sheep grazing on the herbage. He is soon discovered by the wizard, who, taking him for a sheep, fires his arrows at him. The copper covering Â'tsaian has on prevents the arrows from piercing or injuring him. After the wizard had shot all his arrows he climbed the cliff to see why the sheep had not fallen. He walks backwards and forwards upon the brow of the cliff picking up his arrows. As he does this, Â'tsaian runs at him and prods him with his horns, and finally pushes him over the cliff so that he falls down and is killed. Çukçuklakō's and his son now come out of their hiding-place, and the three descend the cliff to where the wizard's body is lying. They now proceed to cut him open, and inside they find the eleven hearts of their dead children. These they take and convey to their original places in the bodies of their sons. They then make some powerful medicine and restore the youths to life again, after which they all proceed home. When they reach their own village, Â'tsaian converts the copper cloth into the figure of a boy, whom by the utterance of magic words he presently brings to life. This boy grows into a powerful man and becomes a great and famous hunter. Being made from copper gives him a decided advantage over other men, for, however much he falls or is knocked about, he is never hurt or injured. He is known by the name *Sqēils*.

TE Skauk', the Raven.

Once upon a time Raven lived by himself in a village of his own. Near by his dwelling was a stream in which he had set his salmon-trap. One day, on going to the trap, he found a fine salmon in it. When he took it home, and was cutting it open, he perceived that it contained two *tlkōi* (milt, or soft roe). He is delighted, and dances about with joy and cries Kā! Kā! Says he now to himself, 'They shall be my wives.' He hangs the tlkōi upon the beams of his house, but cooks and eats the salmon, leaving only the tail end of it. Having eaten so heartily, he feels dull and sleepy, and throws himself down by the fire, with his back towards it, and goes to sleep. While he sleeps he calls to the tlkōi to come down from the beam on which they are hung. They come down and are changed into two comely young women with very white soft skins. They laugh at Raven, and make fun of his scorching back and feet, which are cracking from the effects of the heat. They presently look about for

[1] In the *Diary* of Captain Vancouver, in his remarks on the Sk'qō'mic, he makes brief mention of their 'copper garments.' The allusion receives some light from this story. These 'garments' were probably of this kind.

something to eat, but can discover nothing but the scanty remains of Raven's meal, the salmon tail. This they quickly dispose of, Raven continuing to sleep heavily all the while. Said one to the other, 'I wish I could find Skauk·'s comb; I should like to comb my hair.' The other expressed the same wish, and they both look round for Raven's comb. Presently they discover a little basket containing what they sought, as well as other of Skauk·'s belongings, such as needles, paint, &c. This they appropriate. They comb their hair and paint their faces, laughing all the time at the slumbering Raven, who is snoring heavily. Said one, 'What is the good of a husband with cracked feet and back? Let us go away and leave him.' The other agrees, and they start off, carrying Raven's little basket and its contents with them. The day is very hot. They walk along the beach at the edge of the water towards a distant promontory. As they proceed they shake out some of the paint which the basket contains, and which, being fine, is scattered all about the beach. Since that time the beach always shines and glistens in the sunlight. Just about the time that they were nearing the distant point of land Raven wakes up. The first thing he did was to look up and see if his *tlkōi* were in their place. He finds them gone. He then looks for the salmon-tail he had left over from his dinner, but cannot find it either. Then he searches for his paint-basket, but it, too, is missing. Says he to himself, 'I think the tlkōi must have taken them. I'll go and see if they are outside.' With that he leaves the house and goes down to the water and looks up and down the beach. He perceived the two young women just approaching the distant promontory. 'Ah,' said he, 'they are leaving me. I must go after them and bring them back.' Thereupon he set out to overtake the fugitives and bring them back. But as the fire had burnt and cracked his feet badly while he lay in his heavy stupor, he finds he cannot walk fast. He is obliged to stop frequently and bathe them in the cold water. In a short time the young women pass from his sight beyond the point, and he realises that he has lost them. 'I cannot overtake them,' says he; 'my feet are too sore.' And with that he hobbles back to his dwelling again, crying and groaning as he went. In the meantime, when the young women had rounded the promontory they hear a peculiar noise. This noise resembled the sounds which a Fort Douglas (StlatlumH) woman is said to make with her lips when she wishes to amuse her child or keep it from crying. They look about them, but at first can perceive no one. Presently, however, they discover two old women who are trying to stop the crying of a baby they have in charge, the mother of whom is away in the woods picking berries. Said one of the girls to the old women, who are both blind, 'You don't seem able to stop the child from crying. Here, give it to me.' The old women gave up the child, thinking the girl was the mother returned from her berry-gathering. The two girls carry off the child. Some little time after the mother returns and demands her baby from the old women. Not seeing her child, she cries out, 'What have you done with my baby?' Replied one of the old women, 'Why, we gave it to you just now.' This statement makes the mother angry, and she takes a big stick and beats the old women, crying out that she had been robbed of her child. As she strikes them, one of the pair turns into a *slē'me* (some kind of bird which I was unable to identify), and flies away making the sound peculiar to its kind; the other is transformed into a *Cauk·* (skull). This the angry mother throws into the woods, saying as she does so, 'You can't stay

here.'[1] The mother searches all round for some trace of her child. She walks all night, and early next morning comes upon the girls' tracks. Presently she finds the dead body of her child on the ground, but the two tlkōi women who had taken it had entirely disappeared.

Story of SmEmEtsē'n and Kaiq, the Skunk and the Mink.

Near by the village of Stapās (Gambier Island, Howe Sound) stands a large isolated boulder. This rock a very long time ago, the old Indians believe, was a big *tlā'anukautū'q* or potlatch-house, owned by Mink (*Putorius* (*Lutreola*) *vison*) and his sister Skunk (*Mephitis mephitica*). It was transformed into a huge boulder after the occurrence of the events in the following story. One day Kaiq (Mink) called his sister SmEmEtsē'n (Skunk) to him and bade her store up all her *tsū'som*[2] in a number of boxes. SmEmEtsē'n did as she was instructed, and filled several boxes with the pungent fluid. These Kaiq fastened down in an air-tight manner and stored them in a pile in one corner of the house. After this he sent out invitations to all the animals and birds and fish of the district to come to a big potlatch he was going to hold. On the day appointed the guests gathered in Kaiq's *tlā'anukautū'q*. The building was big enough to hold them all easily, but unfortunately for the Whale the doorway was too narrow for him to get through. Kaiq, prepared for this dilemma, requested him to put his head and shoulders in and remain in that position. With some difficulty the Whale complied with Kaiq's request, and jammed himself in so tight that later, when he wished to retire, he was unable to do so. Now the Mink was on very bad terms with his neighbours the Wolves—indeed, he mortally hated the whole Wolf family, and had actually killed one of them a few days before the feast. He now takes the tail of the dead Wolf and winds it round his head like a wreath and opens the proceedings with a dance. The song which Kaiq sings as he dances is all about the tsū'som of his sister, Skunk. The visitors presently remark to one another, 'What a dreadful song Kaiq is singing!' Kaiq, however, continues to dance and sing, making his way gradually round the building towards the corner where the boxes of tsū'som were stocked. When he is close to the boxes Skunk quickly opens them, as she had been previously instructed by Kaiq, and lets the tsū'som escape. No one suspects the vile purpose the two have in view. They think they are unpacking their blankets and other presents to give them. But presently the pungent, suffocating effluvium fills the whole building, and they realise, too late, what has been done. Unable to get out because of the huge form of the whale blocking the doorway, after many frantic struggles they nearly all succumb to the terrible choking stench, four of them only escaping alive. These are little Louse (*MEtcin*), who crawled into a crack in the building and thus avoided the effects of the effluvium; little Wren (*Qit*), who escaped through a knot-hole in the side of the building; Cod (*Ai'Et*), who also managed to save his life by throwing himself into the water, and who has had in consequence to live ever since at the bottom of the sea; and Mallard, the duck, who flew up to the roof, and thence out through the smoke-hole, in consequence of which all

[1] Hence, say the Indians, arose the custom among them of picking up and throwing away any bones they found lying in their path.

[2] The offensive yellow fluid which the skunk secretes for its defence against its enemies.

Mallard-ducks since that time always fly skyward when they first rise on the wing.

After this trick of Kaiq and his sister, his *tlā'anukautū'*Q with all its contents was transformed into a big boulder, and the tail of the whale may be seen, as the old Indians think, to this day stretching out as a lateral projection beyond the centre of the rock.

TE Sīa'tlmEQ, the Rain-Man.

Sīa'tlmEQ lived in a big house apart by itself. The inmates consisted of himself, his son, and two old women, the name of one of whom was Cauk· (skull). Not very far away in a neighbouring village lived Skauk·, the Raven. For some time past Skauk· had been trying to find some way to induce Sīa'tlmEQ to make some rain. The season had been extremely hot, and the sun had dried and scorched up everything. Everybody had suffered greatly from lack of water, all the streams in the neighbourhood having been dried up for some time past. But nothing he had done hitherto had induced Sīa'tlmEQ to take any notice of him or open his door. It was the opening of the door of Sīa'tlmEQ's dwelling that caused the rain. If the door stood ajar it rained softly; when it was half open it rained heavily; and when it was wide open it came down in torrents. Skauk· sat in the sweltering heat, parched like the whole land with thirst, revolving in his mind how to get the rain-maker to open his door, and so save the people from perishing. Said he to himself, 'I must try and steal his son and then I can make terms with him, so that we shall not be subject to these terrible periods of drought.' But Sīa'tlmEQ's house was very strongly built, and for a long time Skauk· does not see how he can manage to effect an entrance. At length he forms a plan. He calls to him *Tō'tlum*, the flea, *ME'tcin*, the louse, and *Qōā'tEn*, the mouse, and reveals to them his intention and asks for their aid and co-operation. They promise to assist him and do what he desires of them. One evening they all set out together in a big canoe, Tō'tlum, ME'tcin, and Qōā'tEn bringing with them all their relations, so that the canoe was full. They presently arrive at Sīa'tlmEQ's house, which contains no opening save the door, which is fastened very securely from the inside. It was dusk when they arrived, and Sīa'tlmEQ and his household had just gone to bed. 'Now,' said Skauk· to the others, 'you must manage to get in and keep Sīa'tlmEQ and his household from going to sleep till towards morning. They will then sleep the heavier, and we shall be able to do what we want without waking any of them. I will wait outside, and when you have wearied them out and at last permit them to go to sleep Qōā'tEn must open the door and let me in and I will carry off the boy, and then we can make our own terms with his father.' Responded they, 'Oh, we'll get in all right. Strong as Sīa'tlmEQ has made his house, he cannot keep us out.' Thus saying, Tō'tlum sought and found a crack in the boards and, creeping through this, was soon in, followed by all his people. ME'tcin and his people did the same, while Qōā'tEn and his friends found a knot-hole, through which they forced their way. When they were all inside they proceeded without delay to make things uncomfortable for the inmates. The fleas got into their blankets and bit their bodies, the lice into their hair and did the same there, and the mice kept up such a scratching and gnawing that from the three causes together it was impossible for any of them to go to sleep. They tossed and turned, scratched

their bodies and heads, and shook their blankets again and again, but all to no purpose; and not until late in the night, when the mice ceased their noise, and the fleas and lice left them, did they get any sleep. Then, worn out and heavy with sleep, all sank into deep slumber. Qōā'tEn now opened the door and let in the waiting Skauk·, who quietly takes the rain-maker's sleeping son in his arms and carries him down to the canoe. In leaving Sīa'tlmEQ's dwelling Skauk· sets the door ajar, and the rain at once begins to fall lightly. As soon as the child is placed in the canoe they leave the place and return to Skauk·'s house. When they arrive Skauk· takes the still sleeping boy to his house and lays him on his bed. About the time that Skauk· and his friends got home Sīa'tlmEQ woke up and found his door ajar. He soon discovers that his son is missing. He is much grieved and goes out and looks about. As he does so he opens the door wide and leaves it in that position, thus causing the rain to descend in torrents. Suspecting who had robbed him of his child, he presently takes his canoe and makes for Skauk·'s landing. When he arrives he anchors his canoe, but does not get out of it. The rain does not incommode Sīa'tlmEQ in the least. Although he has come some distance in his canoe, and it has been pouring all the while, not a drop has fallen upon him or in his canoe. Wherever he is no rain falls within a certain radius of him. The creeks and streams are now full of water, and the whole land is drinking in the long-desired rain. When Sīa'tlmEQ reached the landing he asked the people if they had seen or knew anything of his son. 'Yes,' they reply, 'he is here. Skauk· has him.' 'Tell Skauk· to come to me,' said the rain-maker, who still sat in his canoe. Skauk· comes down to the water's edge. Said Sīa'tlmEQ to him: 'You have my son here, I learn. Why did you steal him away?' 'Yes,' replied Skauk·, 'your son is here, but I did not steal him. I only brought him here because we were badly in want of water, and I did not know how otherwise to get you to give us rain. I do not wish to rob you of your child,' continued he. All the people were dying for want of water. You would not open your dwelling to me, and so I got some of my friends to help me, and together we found a way to open your door, and while you slept I brought away your son. But I am willing to restore him to you if you will be friends with us and give us rain whenever we want any. I cannot bear to see all the people die and all the berries and roots fail us for want of water.' Sīa'tlmEQ replied: 'Very well, I will be good friends and do as you request, only give me back my son.' Skauk· gives the rain-maker back his child, and the two return to their own house. Before Sīa'tlmEQ left he promised to open his door every now and again from that time on. Said he: 'I will keep my door shut for five or ten or perhaps twenty days, then I will open it again for a little while and you shall have plenty of rain.' As soon as he got home he closed his dwelling and the rain ceased at once. About a week after he opened it again for some time and the rain again fell. This he did from time to time, and has ever since continued to do so; and thus it is that the rain falls on some days and not on others, and we have periods of wet alternating with periods of dry weather.

Skauk· and K·waiē'tEk, or the Origin of Daylight.

Very long ago, in the early days, it was always dark, the daylight being then shut up in a box and carefully stored away in the dwelling of *K·waiē'tEk*, the Seagull, who alone possessed it. This condition of

things had gone on for a long time when Skauk·, the Raven, determined to make his brother K·waiē'tᴇk share his precious treasure with the rest of the world. So one day he made some torches, and lighting some went down to the beach when the tide was out and sought for *sk·ōē'tsai* (*Echini*). Having found as many as he required, he took them home and, after eating their contents, placed the empty shells, with their spines still attached to them, on a platter. These he stealthily takes to his brother K·waiē'tᴇk's house and spreads them over his doorstep so that he cannot come out without treading upon them and running the spines into his feet. Next morning when K·waiē'tᴇk came out of his dwelling he trod upon the *sk·ōē'tsai* shells and ran several of the sharp spines into his naked feet, which made them so sore that he was obliged to keep indoors and nurse them. Later in the day Skauk· came along ostensibly to pay his brother a friendly visit, but really to see how far his stratagem for procuring the *Skōail*, or Daylight, had been successful. He finds K·waiē'tᴇk laid up unable to walk, with his feet very painful and much swollen. 'What is the matter, brother K·waiē'tᴇk?' said the Raven. 'Oh,' responded he, 'I think some of your children must have been playing on my doorstep last evening and left some sk·ōē'tsai there; for this morning I trod upon some as I was leaving the house and the shells must have pierced my feet, and they are so sore and swollen in consequence that I can't put them to the ground without pain.' 'Let me look at them,' said Skauk·; 'perhaps I can find the spines and take them out for you.' So saying, he took hold of one of his brother's feet and pretended to take out the sea-urchins' spines, which had embedded themselves in the flesh, with his knife. He dug the instrument in so roughly, and gave his brother so much pain, that the latter cried out in his agony. 'Am I hurting you?' questioned Skauk·. 'It is so dark I can't properly see what I am doing. Open your Skōail-box a little and I shall be able to see better.' K·waiē'tᴇk did as his brother suggested, and opened the lid of the box in which he kept the Daylight a little way. Skauk· continued, however, to hack away at his foot under pretence of taking the spines out, and presently K·waiē'tᴇk cried out again. Said the Raven, 'If I hurt you it is your own fault. Why don't you give me more light? Here, let me have the box.' His brother gave him the box, cautioning him the while to be careful and not open the lid too wide. 'All right,' said Skauk·, and he opened the lid about halfway. Then he made as if to continue his operation on his brother's feet, but as soon as he turned round he swiftly threw the lid of the box wide open, and all the Daylight rushed out at once and spread itself all over the world, and could never be gathered again. When K·waiē'tᴇk perceived what his brother had done, and that his precious Skōail was gone from him, he was much distressed, and cried and wept bitterly and would not be comforted.

Thus it is that the Seagulls to this day never cease to utter their plaintive cry of k'n-ni - - - i, k'n-ni - - - i.

Tlᴇ Kā'k'laitl, the Witch-Giantess.

Once upon a time a number of children were swimming and playing about in the shallow water on the beach. The children were of all ages—some quite young, others older. One of the oldest of them, a big boy named Tētkē'tsᴇn, was sitting on the beach watching the others, and making some arrows for himself. He was sitting with his back to the

forest, so did not observe that a Kā'k'laitl, or huge witch, was stealing upon them out of the woods. When she got to him she caught him up and threw him over her shoulder into her big *tso'maicin* (basket made from woven snakes). The lad retained his hold of his knife when she dropped him into the basket. She next proceeded to where the other children were huddled together in a terrified group and threw them also, one by one, over her shoulder into the tso'maicin, and carried them off into the forest. She had not proceeded far, however, when Tētkē'tsEn, making use of his knife, cut a hole in the bottom of the tso'maicin, and dropped the smaller children one at a time through the opening on to the ground. They made some little noise as they dropped, thus attracting the Kā'k'laitl's attention. She called out to Tētkē'tsen to know what it meant. Said she, 'What is that sound (*kōmin*) I constantly hear?' Tētkē'tsEn replies quickly, 'It is only the noise of your heels as you walk,' and continues dropping the little ones through the hole, bidding them run home as fast as they could as he did so. By the time the Kā'k'laitl reached her dwelling in the forest none but the bigger children, who were too stout to pass through the aperture, remained in the basket. These she takes into her house; after which she builds an enormous fire, putting into it a great number of big stones. These soon got red hot from the fierce heat. Next she takes some pitch and smears it over the eyes of the children, so that they cannot raise their eyelids or see what is going on. While she was busy over the fire Tētkē'tsEn had warned his companions against this trick of the Kā'k'laitl, and had instructed them to screw up their eyes very tight (*Yā-Ya'*) when she attempted to pitch them. Some of them were careful to regard his injunctions, but others were heedless and closed their eyelids but slightly (*mukm'uk*). When Tētkē'tsEn's turn came he screwed his eyelids together so closely that but little of the pitch got on the lashes, and, on trying a moment after if he could open them, found to his great satisfaction that he could without much difficulty. He then tells the others to open their eyes. Some of the others are able to do so a little; others are not able to separate their lids or see at all. The Kā'k'laitl now places them in a ring round the fire at some little distance from it. In the space between it and them she then commences to dance and sing, arranging at the same time the heated stones as she circles round the fire. The words of her song are *'ntsaqals tE stā'ōkwitl.*[1] Tētkē'tsEn replies, 'Come opposite me, grandmother, but keep your eyes closed or the heat of the fire will burn them.' She continues dancing and singing till she gets between him and the fire. Then he opens his eyes, and, springing forward, gives her a great shove and pushes her into the fire, and she falls on the burning stones. 'Open your eyes,' said Tētkē'tsEn to the others, 'and come and help me keep her down.' They respond to his call, and taking up the spare firewood heap it upon her, covering her up entirely with it. She screams out, *Tlāl camps Tētkē'tsEn! Tlāl camps Tētkē'tsEn!*' 'Take me out, Tētkē'tsEn! Take me out, Tētkē'tsEn!' Replied he, 'We are trying to, grandmother, but you are so heavy.' They continue to pile on more wood, which, presently blazing up, consumes the Kā'k'laitl. But even when her body is consumed her bones still cry out '*Tlāl camps Tētkē'tsEn!*' for she cannot die. They watch the fire burn down and then collect the ashes. These Tētkē'tsEn blows upon and scatters abroad, and they are turned

[1] In good Sk·qō'mic this word is *stāō'tl* or *stauo'tl*, not *stā'ōkwitl.*

into little birds (*tcitcō'c*) known locally as 'snow-birds.' Those who could not open their eyes for the pitch now cried out to Tēktē'tsEn to help them. At first he could do nothing for them, but on looking round the Kā'k'laitl's dwelling he discovers some oil and grease. He rubs their eyelids with some of this, and thus dissolves the pitch, so that they can again open them and see. After this he takes them all home to their parents, who had given them up for lost.

TE Sk'lau, the Beaver.

Once upon a time, long ago, Sk'lau had a large family of boys. Not far off from Sk'lau's dwelling there lived all alone a woman named *QūmE'lōwit* (Frog). It was winter time and the weather was very cold, snow covering all the land and thick ice all the water. Sk'lau called his sons to him and bade them go and gamble (*g·a'·g·Eltq*) with the Ice. 'Play hard,' said he, 'and don't give up till you have won.' So the boys gamble with the Ice and play continuously without break for two days and nights. On the second night Sk'lau goes to the dwelling of QūmE'-lōwit and tells her he wants her for his wife. QūmE'lōwit gets angry and reviles him bitterly. She strikes him and sends him away. Sk'lau is very sad and cries, saying 'c'ā'h! c'ā'h!' As he goes home he hears his boys singing over their gambling. '*Hanī ūa kaitl-kaitl māiyu! Hanī ūa kaitl-kaitl māiyu!*'—'Ice crack open! Ice crack open!'—repeat they. Presently the ice began to groan and crack, and by morning the water is open and the ice gone. When Sk'lau perceives the open water he plunges in, frisking and leaping like a Salmon. Presently the rain begins to fall, increasing in violence as Sk'lau leaps and sings. In a short time the water rises and overwhelms the house of QūmE'lōwit, who becomes greatly alarmed for her safety, and calls out to the Beaver in her fright. '*Ānō'tltcin, Sk'lau! Ānō'tltcin, Sk'lau! Ānōtl, ānō - - - tl*'—'I consent, Beaver! I consent, Beaver! Consent, consen - - - nt'—screamed she. The only notice Sk'lau takes of her now is to call back: 'Cō! cō! I am not such a bad fellow, after all, eh? Like to marry me now, would you?' QūmE'lōwit's house is now full of water, and she struggles with difficulty on to the roof of it. Sk'lau continues his plunging and leaping, and when the water is about to wash her off the roof-top she seizes a log that is floating by and jumps on to it and is carried away. After she had floated about for some time the log is stranded in a strange country. Not far off she sees a large house. She goes forward and peeps in. Within, reclining on his bed, she perceives a man with a very round head and big face. It was the Moon-man. She enters the building and seats herself on the side of the fire farthest from the Moon. Said he now to her, 'Come and sit at the foot of my bed.' 'Do you think I came here,' responded she, 'to sit at the foot of your bed?' 'Come and sit on my lap, then,' returned he. 'Did I come here for that purpose, do you think?' was her reply. 'Come and sit on my breast, then,' said he again; 'perhaps that will please you.' 'I did not come here for that purpose either,' was her response to this invitation. 'Well, come and sit on my forehead then?' To this she consents, and thereupon jumps up on his face, where she has remained ever since.[1]

[1] This story in part strongly recalls that of 'Snūya and the Frog,' which I collected from the N'tlakapamuQ, and which was published in the last Report of the Committee. Whether we are to regard this as the original and the other as a variant form is not perfectly clear. I am myself inclined to regard the N'tlakapamuQ

Te Smai'lEtl, or Wildmen Story.

Once there was a chief who had an only daughter. He possessed also a male slave. Now this slave was accustomed to sleep at the foot of the daughter's bed, his bed lying crosswise at the foot of hers. One night he crept to her side and ravished her while she slept. Some little while later she found herself with child, but was wholly ignorant of the person who had brought this shame upon her, not knowing that the slave had lain with her in her sleep. When she once realises her condition she is anxious to find out who had visited her, and suspecting that the intruder would pay her another visit some night, she takes some paint and smears it all over the palms of her hands. Shortly after the slave pays her a second visit. As it is dark she cannot discover who he is, but before he leaves her this time she presses her paint-smeared hands upon his shoulders and leaves thereon an impression of them without his knowledge. In the morning she is greatly surprised to find that it was the slave who had visited her and whom she had painted on the shoulders. When the chief became conscious of his daughter's condition he was overwhelmed with shame. And, on learning who it was who had caused this disgrace to fall upon him, he took both the guilty slave and his hapless daughter away in his canoe, and, arriving at a certain lofty cliff which overhung the water, he landed them at its base and left them there to perish together. But, although the cliff [1] was always regarded as inaccessible, in some mysterious way the pair managed to climb it. After they had reached the top they travelled inland amongst the mountains till they came to a lake. Here they stopped and built themselves a house, and here the girl gave birth to her child. In course of time many other children were born to them, and when these had come to maturity, as there were no others with whom they could mate, they took each other to husband and wife, and in time a large community grew up around the lake. Though living in a wild state, without proper tools or other utensils, they never forgot their mother's speech, but always conversed together in Sk·qō'mic. The men were exceedingly tall and very keen of scent and great hunters. They always dressed in garments made from the untanned skins of the animals they had slain. From this habit they were called by the Sk·qō'mic, *Smai'lEtl*, or wild people.

APPENDIX III.

The Hurons of Lorette. By LÉON GÉRIN.

Two distinct races of aborigines were found by the French explorers at the opening of the seventeenth century occupying the basin of the St. Lawrence :

1. The Algonquins, nomadic hunters, roving over the lower valley and the northern highlands.

2. The Huron-Iroquois, more sedentary, having some development of

version as a borrowed form which has crept up the river. It is doubtful if the frog is much known within the limits of the 'Dry Belt' in which the N'tlakapamuQ, for the most part, reside. It will be remembered that the events in the N'tlakapamuQ version took place near Spuzzum, the lower boundary-line of the tribe which is immediately contiguous to the upper divisions of the 'Stalō,' or lower Fraser tribes.

[1] The cliff, at whose base the girl and the slave are said to have been left by the irate father, is on the right-hand side of the North Arm of Burrard Inlet. Some way back in the mountains there is a beautiful little lake, now well known to trout-

agriculture and a better defined organisation, settled in the region of the three great lakes, Ontario, Erie, Huron ; the Hurons, to the north of Lake Ontario ; the Iroquois, to the south of it ; the Neutrals, to the north of Lake Erie ; the Eries (or Cats), to the south of the same lake.

The Hurons (otherwise called Wyandots) alone numbered some 25,000, and their villages were spread from Toronto to the Bay of Quinte, and from Lake Ontario to Georgian Bay.[1] From the north-westerly projection of that territory to which they had been driven by degrees, the Hurons, after their overthrow by the Iroquois about 1650, were dispersed in all directions. Broken fragments of the nation became the foundation stock of the small Wyandot communities still extant in the Indian Territory of the United States,[2] in Essex (Ontario), and at Lorette, near Quebec.

This paper is the result of an inquiry carried on during the summer of 1899 into the social conditions of the Hurons of Lorette. The object was specially to ascertain the present status of the race, the degree of its variation from the primitive type, and the influences which brought about such variation. The method followed was that of social observation as initiated by Frederick Le Play, perfected by Mr. Henri de Tourville, and propounded by *l'École de la Science Sociale* of Paris, and its leader, Mr. Edmond Demolins.

The facts descriptive of the present social conditions have for the most part been collected by the writer in the course of two short visits to Lorette. As for the historical and general scientific data which supplement and explain the former, they were obtained from original sources, reference to which is made.

Physical Features.

Lorette (also called Indian Lorette, or Jeune Lorette, to distinguish it from l'Ancienne Lorette) lies 46° 51′ N. lat. by 71° 21′ W. long., on the north side of the river St. Lawrence, eight or nine miles inland N.W. of Quebec.

At this point three natural zones are observable in close succession :

1. Lorette itself stands on the brow of an elevated terrace which marks the southerly limit of the Laurentian formation, and from which the river St. Charles descends through a steep and narrow gorge.[3] That terrace, which extends some eight or ten miles towards the north, has a flat and almost horizontal surface ; but its soil, though generally deep, is sandy and rather poor. The land has been partly cleared of woods, but agriculture has not developed over it to any great extent. Along the upper course of the river St. Charles, back of Lorette, no farms are to be

fishers, which answers to the lake of the story. The Sk·qō′mic firmly believed in the existence of these Smai′lEtl. The old Indians say they sometimes saw them when out hunting. Whether such a community once really existed it is impossible now to say. But, at any rate, no such tribe or people has ever dwelt in the mountains in the memory of the oldest settlers here.

[1] A. F. Hunter, *Transactions of Canadian Institute*, Toronto, 1889, 1892. G. E. Laidlaw, *Ontario Archæological Report*, 1899, p. 46. Compare Champlain (Québec, 1870), vol. iv. p. 36, vol. v. p. 25 6.

[2] *United States Census*, 1890, Indians, p. 248.

[3] The water supply of the city of Quebec is taken from this river, a very short distance back of Lorette. The 'Château d'Eau' is said to stand at an altitude 130 feet greater than the citadel built on the rock which overlooks Quebec.

seen, but instead, an after-growth of scrubby spruces and the summer villas of some professional men of Quebec.

2. To the south of Lorette, and overlooked by it, there stretches a belt of land eight miles wide ; a low plain through which the river St. Charles slowly winds its way to its estuary ; a valley scooped out between the sandy terrace just described and a narrow ridge which forms the north bank of the St. Lawrence. The soil of that second zone is generally deep, fertile, and particularly well adapted for agricultural pursuits. As evidence of that, fine expanses of cultivated fields interspersed with comfortable farmhouses, cosy villages, and glittering church steeples are to be seen along the lower course of the St. Charles, over its rich bottom lands or loamy hillsides.

3. Towards the north the sandy terrace of Lorette merges into a vast mountainous tract which extends to Hudson Bay and the Atlantic Ocean, interrupted only by the valley of Saguenay and Lake St. John. These North Laurentian highlands present a succession of rocky, rounded summits cut by narrow valleys, with sparse, limited areas of shallow soil. A land well adapted for the production of timber, especially for the growth of the Coniferæ, and originally a tract abounding in fur-bearing animals, but over the greater part of its extent offering little inducement to agricultural settlers, who of late years only have taken a foothold within its borders.

In other words, Lorette lies at the meeting point of two great regions widely different in their productions and capabilities : the Champaign region bordering on the St. Lawrence, and the North Laurentian highlands ; the former restricted and narrowing, the latter, on the contrary, expanding at this point of the valley. Lorette is still within the Champaign region, not, however, on its inner fertile zone, but on its outer sandy zone ; and adjoining it, or in close proximity to it, there are, on the one hand, a fine agricultural country, on the other a rugged wilderness.[1]

The geographical position of the Hurons of Lorette is very similar to that which was occupied by their ancestors, in the vicinity of Lake Simcoe, during the first half of the seventeenth century. Though some 400 miles to the west of Lorette, and 150 miles nearer to the equator, the old Huron country was situated alike on the border of that great Laurentian formation, betwixt mountain and plain, with to one side a vast natural hunting ground, and to the other deep soils inviting tillage.

However, as regards soil and climate, the habitat of the ancient Hurons was more favoured than the sandy terrace of Lorette. Champlain and the early explorers who ascended the river Ottawa and its tributary, the Mattawa, and by way of lake Nipissing, French River and the shores of Georgian Bay, reached the Wyandot settlements adjoining Lake Simcoe, were much impressed by the pleasantness and fertility of that country compared with the rocky solitude they had just traversed. They write in glowing terms of Huronia, its extensive clearings, its fields of maize, sunflowers, and pumpkins, its fruit trees, in the midst of gentle hills and verdant plains watered by many a stream. The soil, though

[1] In the mapping of the natural zones surrounding Lorette the publications of the Geological Survey of Canada have been very helpful. The map showing the superficial deposits between Lake Superior and Gaspé (Atlas, 1863) and the map of geological formations in the province of Quebec attached to Dr. Ells's report for 1887, are here specially referred to.

somewhat sandy in places, they say, is on the whole well suited to the growth of Indian corn.[1]

To-day the counties of East and North Simcoe, which comprise the greater portion of the later settlements of the Hurons, support a farming and trading population of over 65,000 whites. They are thriving sections of a highly prosperous province.[2] In contrast the sandy terrace back of Lorette, even up to this time, is sparsely settled, and, like the Laurentian highlands to the north, remains almost untouched by agricultural enterprise.

Labour.

Sixty-two families, or about 300 men, women, and children, make up the resident population of Indian Lorette.[3] The forms of labour through which these people support themselves are as follows, in the order of decreasing importance : (1) Hide-dressing ; (2) moccasin-making ; (3) snowshoe- and canoe-making ; (4) basket-making and fancy wares ; (5) hiring out as guides ; (6) hunting and fishing ; (7) farming.

Hide-dressing.—From 10,000 to 15,000 hides are dressed yearly at Lorette. These hides are for the most part imported, East India elk and antelope making the bulk ; caribou (*Tarandus rangifer*) and cow, the produce of the region, are used in certain quantities, as also a few moose pelts.

The dressing processes are very simple. The green skins are first steeped in water, mere barrels sunk in the ground in an open field serving the purpose. Once thoroughly soaked the skins are scraped ; the inner (meat) layer and the first outer (hair) layer of the hide are thereby removed. (The scrapings are sold to manufacturers of glue.) Then other labourers take the skins and wash them in soap emulsions, and afterwards sprinkle them with oil. Codfish oil is used for this. The skins are then rubbed with sand-paper, and finally passed through a smoke-house, similar to that used in the curing of hams. At various stages of preparation the skins are put up to dry on scaffolds made of poles connected by rails to which hooks are attached. These scaffolds, or 'chantiers de peaux,' are a characteristic feature of Lorette. Not only do they cover two or three large fields adjoining the village, but, as well, smaller patches within the village plot. With the smoke-house and the hide-wringer they constitute practically the whole plant required for the dressing of hides.

The hide-dressing industry at Lorette is centred in three or four fairly large establishments managed by private enterprise, and in connection with which the manufacturing of moccasins and snowshoes is carried on. The head of each concern owns or rents the grounds and buildings, owns the plant, purchases the green hides and accessories from importers in Quebec, and pays his help wages by the day or month. The hides thus dressed are not sold, but utilised on the same premises, principally in the manufacture of moccasins.

[1] Champlain, *ibid.*, vol. iv. pp. 27, 30, 31 ; Brébeuf, Jesuit Relations (Thwaites's edition), vol. viii. p. 115.

[2] *Census of Canada*, 1891, vol. i. p. 66, ii. pp. 66, 174.

[3] The writer is indebted to Mr. A. O. Bastien, Government agent at the Huron Reservation, for much of the information contained in the following pages. Mr. Cloutier, the owner of a hide-dressing and moccasin-making establishment at Lorette, kindly supplied many facts relative to the various industries, as did also Mr. Maurice Bastien, who controls a large concern in the locality.

Moccasin-making.—The output at Lorette in 1898 was about 140,000 pairs.[1] The first operation is the cutting of the hide. It is done, in workshops connected with the dressing-grounds, by the boss himself or by specially skilled workmen under his supervision. These workmen are paid by the day or piece. The work is performed by means of a sharp knife and various wooden forms. It requires some skill to make the most of a hide, to cut out of each skin the greatest possible number of bottoms, tops, and uppers with the smallest possible proportion of useless cuttings. This is the main operation in the hide-dressing and moccasin-making business, that which is left to the boss, or head of the industry, whenever he takes a hand in the work. The three processes which follow, viz. (1) embroidering of the top piece, (2) turning up of the bottom piece and sewing-on of the top, and (3) sewing-on of the upper piece, are not accomplished by men at the workshop, but in the village homes by women making a speciality of one of the above operations. They are paid by the piece.

Moose-hair, dyed in bright colours, serves for embroidering the top piece. Twenty-five to thirty cents per dozen pairs are the wages paid for that work, and a woman, besides attending to her daily house-work, may find time to embroider from one to two dozen pairs a day. The second and third processes above mentioned are each paid for at about the same rate as the first, and an equal amount of work may be accomplished by hand at each one of them by one person in a day. By means of a sewing-machine three dozen pairs of moccasins may be sewed in a day's work. To increase their earnings in that way, some of the Lorette women have provided themselves with sewing-machines. When shoemaker's thread is used instead of the ordinary, the wages paid run as high as one dollar a dozen pairs. The moccasins are then returned to the central workshop, where, by means of three simple apparatus, holes are punched through the uppers, eyelets fastened on to one side, and hooks to the other. Laces are made of strips from the edgings of the hide. Finally the moccasins are packed and shipped to distant points. They are sold wholesale to large dealers in towns and cities throughout Canada and the United States; in late years large quantities have been forwarded to the Klondike.

Snowshoe-making.—Seven thousand pairs of snowshoes were turned out at Lorette in 1898; but the demand was larger than usual that year consequent on the opening up of the Klondike. That same year as many as 20,000 hides were dressed in the locality and 12,000 dozen pairs of moccasins manufactured. The following year there was a marked falling off in the demand, especially of snowshoes, the Lorette snowshoe not having been found of as suitable a shape as other makes for use in the Klondike. Cow-skin is largely used for the netting of the snowshoe, and ash wood for the frame.

It should be noted that in the various industries carried on at Lorette there are not only Hurons engaged, but a number, quite as large, of French Canadians residing at St. Ambroise, across the river. This is particularly the case with the moccasin-making industry, in which many French Canadian women take a hand. Snowshoe-making is an exception to the rule: it is still a distinctive Huron industry, only two French Canadians being trained in the art.

[1] See *Dominion Government Blue-book, Indian Affairs*, 1898, Bastien's Report, p. 45.

About twenty-five canoes are made and sold every year. Fine birch bark suitable for canoe-making is not very easily found within reasonable distance, and most of the canoes turned out at Lorette are made of canvas purchased from Quebec dealers.

Some years ago lacrosses were manufactured in certain quantities; but very few are made now. Toboggan-making is also an industry of the past here. Competition has killed it, toboggans manufactured at Montreal and elsewhere being considered of better quality.

Basket-making and Fancy Wares.—With ash wood and sweet hay the Huron women manufacture baskets of ornamental designs and various small wares: fans, boxes, reticules, toys, &c. The men occasionally lend a hand in preparing strips of ash and discs of various woods, but the women and girls practically have the industry to themselves. Contrary to the preceding, this industry is not a traditional one of Lorette: it was introduced here from the Abenakis Reservation of St. Francis (on the south shore of the St. Lawrence) some fifteen years ago. It has not developed to the same extent as hide-dressing and moccasin-making, and is still essentially a home industry. Several families have large displays of these Indian wares in their houses. Part of the output is disposed of, as in the case of moccasins and snowshoes, to dealers in large cities; the bulk is sold by the Hurons themselves to visitors in their village, or taken by them to summer resorts and centres of population, and there retailed.

Of late a severe blow was dealt to this businesss through the withdrawal by the United States Government of the privilege exempting Indians from paying duty on their wares when entering that country.

Guiding.—Several of the Lorette Hurons hire out periodically to parties of sport seekers on hunting or fishing excursions into the interior. This is a favourite occupation of many of the men. While thus engaged they earn one dollar and twenty-five cents per day, besides their living expenses.

Hunting and Fishing.—Like the preceding a favourite occupation of the Hurons, though (except for a very few) it is not any longer an important means of livelihood. In 1898, the revenue derived from hunting by the Lorette community was estimated at 800 dollars, and that from fishing at 100 dollars.[1]

Beaver, otter, marten, mink, and caribou are still found in fairly large numbers over the vast unsettled tract which extends towards the north. The upper courses of the rivers St. Charles, Jacques-Cartier, Ste. Anne, &c., which lead into that wilderness, are much interrupted by rapids, and canoes cannot be much used as means of conveyance. The hunters proceed on foot, sometimes right across the streams. Otter and beaver are the most valuable of the fur-bearing animals. The furs are generally sold undressed to large dealers in Quebec. Caribou are found in abundance, and they provide good meat, but their skin is of little value. The skin of the moose is worth three or four times as much; but moose is scarce now in this part of the country. To find it hunters have to cross the St. Lawrence and reach the plateaus of Northern New Brunswick and of Maine. They do so by railway.

The Hurons of Lorette bitterly complain of interference with their hunting privileges on the part of the whites through governmental regulations, leases to clubs, and the creating of a national park north of

[1] *Indian Affairs,* 1898, p. 468.

Quebec. Forest rangers are on the look out, and frequently confiscate the pelts and destroy the traps of the Indian hunters.

Farming.—The Huron villagers do not seek any appreciable part of their income from agriculture, nor even from those more simple opportunities afforded by country life. Only three or four families keep a cow each, and some hens ; only a few have a small kitchen garden ; the others purchase from French Canadian farmers the very milk, eggs, and vegetables they consume. Only one of the villagers keeps horses.

Two miles to the west of Lorette village there is a reserve 1,600 arpents (1,350 acres) in area, on which six or seven Huron families are supposed to be farming. Although they may occasionally turn out a few pairs of snowshoes, they do not resort to industries in at all the same measure as do the Lorette villagers. At the same time they can hardly be considered farmers. Much the greater part of the reserve is still bush. Each farm comprises a few arpents (at most ten or twelve) of cleared land, on which the only growth to be observed, apart from a small garden and potato patch, is a miserable field of very thin hay overrun by the ox-eye daisy. In rare instances a crop of a few bushels of oats may be added. When any farm animals are kept, the stock comprises one cow (exceptionally two), one horse (if any), one or two porkers, and about as many hens. Attracted to one of these homesteads by the rather better appearance of the house and the barn compared with the hovels on most of the other clearings, we were disappointed to find that the husbandry there carried on was of the same general undeveloped type. We did not see any stock, but were met by the fierce barking of three or four dogs coming out in succession from under the doorsteps. 'They are very good hunting dogs,' the people told us by way of apology.

For the Hurons of the reserve a more congenial means of living than agriculture is hunting. We had an hour's chat with Thomas Tsioui, a typical old Huron. Three of his sons still living are hunters as much as conditions permit ; he himself spent the greater part of his early life in the woods. At one time he was a noted long-distance runner at the Quebec and Montreal fairs.

In 1898, the revenue derived from farming by the whole Huron community was estimated at 870 dollars.[1] The revenue obtained from their farms and from the chase are insufficient for the support of these Hurons of the reserve, and they would be in utter misery were it not for some additional revenue from various sources : drawing firewood from the reserve to the Lorette villagers, day labour performed on the railway and elsewhere in the vicinity, and oftentimes the very material help provided by their women folk.

With all that, a large proportion of the Lorette Indians have been forced to seek elsewhere their means of livelihood. The Huron community reckons 142 absentees against a resident population of 300. That is to say about one-third of the total number has left for other parts of Canada or for the United States. Now and then some of these effect their return to their old abode, while others start out in their turn.

The means of living of our modern Hurons as just described do not at

[1] That same year the revenue derived from the various manufacturing industries amounted to 27,500 dollars, and wages earned to 9,000 dollars, giving for the Hurons of Lorette a total income from all sources of 38,000 dollars. The following year (1899) the returns were as follows: Manufacturing industries, 18,000 dollars; wages, 5,000 dollars; hunting and fishing, 1,050 dollars; farming, 1,200 dollars.

first sight appear to have any connection either with the previous social status of the race, or with the physical features of its present habitat. In a general way, with the ancient Hurons, agriculture and hunting were the principal means of living; to-day at Lorette, labour in both these forms has been almost entirely given up. In their stead manufacturing industries have grown—industries, besides, which do not depend for their raw material on the resources of the locality, and which find in the vicinity a market for only a very small portion of their output.

However, from a perusal of the documentary evidence available, old and new, and from what could be gathered in conversation with men and women at Lorette, I obtained some insight into the process of evolution from which the labour system of the Hurons has resulted.

Their ancestors in Western Ontario supported themselves chiefly by hunting, fishing, and agriculture. The young men were hunters and warriors; the older male members of the tribe, fishermen; the women, tillers of the soil, growers of maize, beans, pumpkins, sunflowers, and tobacco. Besides, the Hurons were trained in the practice of a number of home industries. The men built huts made of saplings, and which in the words of Parkman 'were much like an arbor overarching a garden walk.'[1] The men, as well, made their own bows and arrows, fishing nets, stone axes, bark canoes, toboggans, snowshoes, and lacrosses. The Huron women ground the corn, smoked the fish, spun the wild hemp for the fishing-nets, dressed deer skins, and from them made moccasins, which they embroidered handsomely, and out of the furs of the beaver, the porcupine, &c., prepared various articles of clothing.[2] In some of these industries the Hurons were not found as expert as their neighbours of Algonquin stock, but they surpassed these in commercial aptitudes, having from time immemorial acted as middlemen between the tribes to the north and those to the south in the exchange of various commodities, and, after the advent of the French, becoming the purveyors and carriers of their fur trade.[3]

After taking up their abode in the vicinity of Quebec, the Hurons were subjected to new conditions, the result of the close neighbourhood and competition of the French colonists, combined with the physical features of the country. These conditions in the first place tended to keep them away from agriculture.

The traditional mode of farming of the Hurons was very imperfect. It consisted in the production through female labour of supplies of vegetables and maize for family needs. No live stock, no beasts of burden, were kept. Thus, being without the means of manuring the land or drawing fuel long distances, they had to change their location as soon as the fertility of the soil and the supply of firewood within a limited area were exhausted. Such had been the practice in the old Huron country; such it continued to be with the Huron refugees about Quebec. But here, while the Indians were always free to desert their village site for a new one farther inland, they were no longer at liberty to retrace their steps. The influx of white settlers at their back prevented them from moving in any but one direction. In that way the Hurons, who after their arrival amongst the French colonists had been located on the lowlands bordering the river St. Lawrence, receded gradually from the

[1] *Jesuits in North America*, Little Brown, Boston, Int. XXVI.

[2] Champlain, vol. iv. pp. 79–82, 101.

[3] Champlain, *ibid.*

front, until in 1697 they found themselves evicted from the fertile belt, relegated to the sandy terrace close on the mountain tract. Under such conditions they could not be expected to make any great advance in agriculture.[1]

While both the social and the physical environment about Quebec tended to check the agricultural progress of the Hurons, these same conditions at first favoured their propensity for the chase and for warlike occupations. At their doors that great Laurentian mountain tract extended, abounding in fish, game, fur-bearing animals; and for all these natural productions Quebec offered a near-by and ready market. Besides, their close association with the white settlers enabled them to obtain assistance and employment in various forms. As long as the French régime lasted, and for half a century more under the British rule, the Hurons appear to have supported themselves chiefly through the sales of furs and allowances for military service. References to them in the documents of that period (the writings of the missionaries excepted) are mostly all in connection with the fur trade or with war parties.[2] In 1730, a church was built for their use, and their contributions were paid in furs, apparently their most valuable and abundant commodity.[3] A conspicuous feature of Lorette to the present day is a large, low, massive stone structure, which is said to have been originally a post of one of the fur-trading companies, and which subsequently became the property of a noted Huron chief, Picard, himself a trader in furs.

During the whole of the eighteenth century the traditional industries of the Hurons do not appear to have been developed beyond the measure of the family needs. It is not until the early part of the nineteenth century that we notice a change in this respect. The facts adduced before a committee of the legislative assembly of Lower Canada in 1819 and 1824 show that for some years previous the Hurons of Lorette had been sustaining themselves to some extent through the manufacture and sale of moccasins, snowshoes, toboggans, fur articles of dress, and various fancy wares.[4] This new feature had been brought about as a result of the constant decline of their agriculture, and more especially, at a subsequent date, by the decline of the chase itself, as also by the reduction of the war allowances. It should be noted, moreover, that as the Hurons, under the influence of environment, were slowly improving their mode of living, larger and more regular returns than those ensured by hunting were necessary to keep them in comfort. By manufacturing they enhanced the value of the furs, and thus made up in part for their greater scarcity and for the deficiency in the returns from other sources. For many years these industries were carried on by the Huron families in a very small way, at first exclusively by the women, and then by both men and women, but on a small scale. Both hunting and plot farming were prosecuted in conjunction, but the latter especially remained at a very low stage, or even decreased, while the manufacturing industries all the time were growing.[5]

[1] *Titres Seigneuriaux*, Quebec, vol. i. p. 428; Charlevoix, *Journal*, p. 83; Peter Kalm, *Société Historique de Montréal*, 1880, p. 124.

[2] *Documents de la Nouvelle-France*, vol. iii. pp. 23, 58, 87, 108, vol. iv. p. 112.

[3] Franquet, *Journal de Voyage* (MSS. Parliament Library, Ottawa), p. 141.

[4] Journals of the Assembly of Lower Canada; Bouchette, *Topographical Dictionary*, verbo 'Indians.'

[5] *Journals*, Assembly, Lower Canada, 1835; Assembly, United Canada, 1844-5, 1847, 1856.

Some twenty-five or thirty years ago there took place an important social phenomenon which completed the transformation of the labour system of the Hurons—the spreading throughout Canada of the world-wide commercial and industrial evolution, the introduction of machinery, the building of railways, the extension of great transportation agencies. Man's power of production was thereby increased a hundredfold, and distance suppressed, so to speak. While some of the minor industries of Lorette, such as toboggan-making and lacrosse-making, received their death-blow from the new order of things, it instilled a new life into some others—hide-dressing, moccasin and snowshoe making. No longer dependent on local conditions, no longer restricted by the short supply of raw material at hand or by the limited demand from near-by markets, these industries attained the high degree of development which we have seen. A new industry, fancy basket-making, was introduced. The development of manufacturing industries thus brought about, with the opportunities for constant earning of wages at generally pleasant tasks, in turn became a further cause of desertion of agriculture. Even hunting is no longer considered a regular means of livelihood, and is largely replaced by the more profitable occupation of guiding through the woods sportsmen from the cities.

A Huron woman, ninety years of age, with whom I conversed at Lorette, had witnessed many phases of that evolution of labour. She remembered the time when patches of Indian corn, pumpkins, beans, and potatoes were grown in connection with almost every home in the village. The women did most of the garden and field work, while the men did very little but hunt and play lacrosse. She saw agriculture given up gradually, while the Hurons were taking more and more to manufacturing.

Notwithstanding the evolution through which their labour system has been made to pass, the Huron community as a whole exhibit traits retained from the previous social status. The men are less industrious than the women : they still entertain a dislike for agriculture and steady work ; they abstain from working in factories.

Property.

The property held in trust for the Hurons of Lorette comprises : (1) the village site, about 20 arpents in extent ; (2) adjoining the latter, a common covering, 9 arpents ; (3) two miles from the village, the reserve proper, 1,600 arpents (1,350 acres) in extent ; and (4) some thirty miles back of Lorette, the Rocmont Reserve, in the county of Portneuf, 9,600 acres in area.

1. The village plot is subdivided into small lots, each family being entitled to an area sufficient for a house, besides a width of 30 feet in front and 3 feet at the back of that house.

2. The common was originally, as indicated by its French name, 'Clos des Cochons,' a pasture for hogs. It still continues to be owned in common by the Huron community, but is now used almost solely as a hide-dressing ground by Mr. Maurice Bastien, who has erected thereon sheds and drying scaffolds.

3. The 1,600 arpents reserve also remains undivided. It was granted to the Hurons for their supply of fuel. The greater part is still bush. Six or seven families, as we have seen, have taken up their abode there as farmers ; but the farming carried on is of such a primitive character

that it has not been found necessary to trace any boundaries between the various farms.

The above three areas were allotted to the Hurons about the end of the seventeenth century, or the beginning of the eighteenth, by the Jesuits, under whose charge they were placed. The deed confirming the grant was not passed till 1742 (for the last) and 1794 (for the two others). It is all that is left to the Hurons of the seigniory of Sillery.[1]

4. The Rocmont Reserve is wholly a mountainous forest tract set apart by the Canadian Government in recent times for the support of the Hurons of Lorette, but neither occupied nor worked by them. However, they derive some revenue from it, the cut of pine and spruce over its area being leased out every year to lumbermen, and the proceeds usually paid to the 'band' in the form of allowances.

It is a remarkable fact that all this property is still held in common. With the Hurons of Lorette private ownership of land does not exist. Neither have they any desire, as far as I could ascertain, to individually own land. To my knowledge only one Huron to-day holds privately some land—not in the reserve, but adjoining it. In the past, as well, such cases of private ownership have been exceedingly rare.

On the other hand, at Lorette almost every family owns the house in which it lives, at any rate so long as it continues to occupy it. Movables, wearing apparel, &c., are, of course, also recognised private property, as are wages and earnings from various sources.

This system of property of the Hurons of Lorette does not differ materially from that of their forefathers. The ancient Hurons, as we have seen, did not put much labour on the soil, and correspondingly their hold on the soil was of a weak and limited sort. From Champlain and Brébeuf we learn that they had no permanent tenure of land, as evidenced by their change of abode at frequent intervals. At the same time, with them all movables—as, for instance, the produce of the chase, the earnings from trade—were subject to family or individual appropriation. Inequalities of wealth from this source were quite apparent in the Huron villages of old. Even monopolies were recognised by the ancient Hurons, inasmuch as individuals who had opened a trade or discovered a market were granted for themselves and their kindred the exclusive right of carrying on that trade or supplying that market, or were permitted to levy tribute on those desirous of taking advantage of the new opening. A difference, however, from the conditions of things in existence to-day at Lorette was the prevalence of theft in the Huron villages of old and its lax repression.[2]

After their removal to the vicinity of Quebec, the Hurons, as we have seen, did not take more energetically to the cultivation of the soil; on the contrary, under the new conditions they gave up little by little the practice of agriculture. Similarly they did not develop any greater aptness to hold land either privately or collectively.

In 1651, the King of France bestowed on the Christian Indians settled in the vicinity of Quebec (of whom the Hurons were the nucleus) a grant of land covering three miles in width on the river St. Lawrence by twelve miles in depth, the seigniory of Sillery. Of course, the Hurons were

[1] The originals of the deeds are in the archives of the Department of Indian Affairs, Ottawa. I have to thank Mr. Samuel Stewart and Mr. D. C. Scott for their kindness in facilitating my inquiry.

[2] *Jesuit Relations* (Thwaites), x. pp. 223, 225.

quite unprepared to take advantage or retain possession of such an extent of territory, especially in a region where arable land was rather scarce and greatly in demand. They allowed themselves to be dispossessed piecemeal of the land itself, and of the seigniorial dues attached to it as well, and were left with holdings totally inadequate for their support and advancement.

In short, the system of property of the Hurons of Lorette is characterised by the absence of private holdings and the limitation of the collective holdings. These conditions are the direct outcome of the forms of labour which they retained or adopted under the combined influence of their own traditions, of the physical features of the country around Quebec, and of social environment and competition.

These property conditions, in their turn, have had far-reaching effects on the further social evolution of the Huron community. They permitted its being closely surrounded and permeated in its home life by outside (principally French Canadian) notions and manners. The village of Lorette is inextensive, and so penetrated by the adjoining settlements, that on its outskirts, at many points, Huron homes almost join those of white neighbours, and it is often a difficult matter to say where the line of demarcation passes. The consequences of this close neighbourhood will appear presently.

Family.

The family group at Lorette is quite restricted. Each household, as a rule, consists of a single family, comprising only a few persons; for instance, the husband, the wife, and two or three young children; in other cases an aged couple alone, or possibly assisted by a grown-up daughter or son. When barely eight or ten years old the Huron boy or girl takes to manufacturing fancy wares at home, and soon acquires a training in the various arts. At twenty or twenty-two they marry, and take up house separately from the parents. If they have decided to remain at Lorette, and are not already provided with a lodging there, they apply for a lot from the village council, and build a house for themselves. In recent years the development of industry has induced several newly married couples to take up their home in their native village; a new street, or rather lane, had to be opened, and still another will be opened soon.

The restricted family group of the Hurons of Lorette is very unlike the patriarchal household of their ancestors, wherein eight or ten, or even as many as twenty-four, families lived under one roof.[1] Apart from that close material grouping into large households, there existed, among the ancient Hurons, social groups much more comprehensive—clans founded on consanguinity. At one time there were as many as twelve clans, among which the Huron families were distributed.

'The unit of the Wyandot social and political systems,' writes Mr. W. E. Connelly, whose knowledge of the Wyandots settled in the Indian Territory of the United States is most thorough, 'was not the family nor the individual, but the clan. The child belonged to its clan first, to its parents afterwards.'[2]

The clans were not mere local organisations; they were ramified throughout the whole territory, throughout the whole nation; so that while the people, for purposes of livelihood, were dispersed in distant

[1] Champlain, vol. iv. p. 74.
[2] *Ontario Archæological Report*, 1899, p. 107.

villages, and for purposes of government were divided into five or six tribes or sub-nations, still they held fast together by the strong bond of the clan founded on family relationship.

A peculiar feature of the Huron-Iroquois clanship was that it existed and was transmitted, not through the men, but through the women of the tribe or family. The Huron child did not belong to the clan of his father, but to that of his mother. In the same way the possessions of a deceased Huron warrior did not go to his sons, but to his brothers, or to the sons of his sisters ; that is, to members of his own clan.

At Lorette to-day no trace is to be found of the old Huron clanship in the social institutions ; even the memory of it is almost effaced. The members of the band whom I questioned on the subject were not totally ignorant of the clan system, but they invariably connected it with male descent. One Huron, ninety years of age, and another seventy-six years of age, told me they belonged to the clan or 'compagnie' of the Deer, their reason for saying so being that their father had belonged to it. Another claimed to be of the 'compagnie' of the Tortoise, also because his father had been of that clan ; and to remove my doubts he added : 'How could I belong to a Huron clan through my mother, who was a French Canadian ?'

Old Thomas Tsioui (whose name has been mentioned previously) expressed somewhat similar views to me. His contention is that the Tsiouis are the only genuine Hurons at Lorette ; that all the others are descendants of French Canadians who stole their way into the Huron community. As I objected that the Tsiouis themselves could not claim pure Huron extraction, their mothers and grandmothers in most cases being French Canadian women, the old man argued with great warmth that man, and not woman, the husband, not the wife, made the race. He was seemingly unaware that this was the very opposite of the Huron doctrine, and that his use of such an argument was good proof to me that he was no longer a Huron in respect to some of the fundamental traditions of the race.

A simple phenomenon which marks the evolution of our Hurons from the patriarchal community and clanship of their ancestors to the reduced family group of to-day is the adoption of distinct family names, transmitted from father to son. With the old Hurons there did not really exist any permanent family names other than the general designation of each clan. Each individual was given a name distinctive of himself and of his clan as well, but which, as in the case of the first name with us, he did not transmit to his progeny. 'Each clan,' writes Mr. Connelly, 'had its list of proper names, and this list was its exclusive property, which no other clan could appropriate or use. . . . The customs and usages governing the formation of clan proper names demanded that they should be derived from some part, habit, action, or some peculiarity of the animal from which the clan was descended. . . . Thus a proper name was always a distinctive badge of the clan bestowing it. When death left unused any of the original clan proper names, the next child born into the clan, if of the sex to which the temporarily obsolete name belonged, had this name bestowed upon it.' [1]

After the missionaries had converted the Hurons to the faith they introduced Christian names, which for many generations were used

[1] Connelly, *Ontario Archæological Report*, 1899, p. 107.

concurrently with clan designations, but in the end superseded them. Most of the family names at Lorette are Christian names which have become permanently attached to the various households : Romain, Vincent, Gros-Louis, Bastien (for Sebastien). It was in the early years of the present nineteenth century that family names became permanent at Lorette, and transmissible from father to son. There are to-day 21 families of Tsiouis, 13 Picard, 12 Gros Louis, 6 Vincent, 4 Bastien, 2 Romain, besides 3 de Gonzague (of Abenakis extraction), and 1 Paul (of Malecite extraction).

From the organisation of the family group, if we turn to its internal management, we find, in the first place, that the parents' authority over the children is of limited extent. Very little restraint is put on the children. Constant intercourse between the various households in that crowded village tends to lessen the action of each separate group over its children. These, at an early age, as we have seen, acquire a training in handicraft and become important factors in the welfare of the family, or at any rate independent of it for their livelihood. In that respect the Hurons of Lorette still resemble to a certain extent their primitive ancestors, who allowed their children great freedom, and never chastised them.[1] Among the ancient Hurons the laxity of parental rule was the natural result of the development of hunting and of warlike pursuits, in all of which the young men had necessarily a superiority over the older members of the family. With the Hurons of Lorette the same lax family government continued to prevail, owing to the long maintenance of the chase as their principal means of living, only to be displaced in recent times by industries which afford to the young great facilities for the establishment of separate independent homes.

Nevertheless morals are not bad. They are certainly greatly in advance on what they were in olden times. But the result is due almost wholly to outside influences—religious action and social environment. The morals of the ancient Hurons were of a very low order : debauchery was rampant in their villages.[2] When, after their overthrow by the Iroquois, they fell under the rule of the Jesuit missionaries, a strict code of monastic morality was enforced upon them.[3] The greater number submitted to it, not, however, through any strong personal sense of duty and self-respect, but impelled by fear of exclusion from the reserve or of the infliction of some public penance. Accordingly, under the British régime, as soon as the strong hand of the Jesuit was withdrawn, the Huron morals relaxed, and, under the influence of the corrupt elements from the near-by city, fell to a very low plane. In the course of the nineteenth century Lorette became 'the constant resort of the dissipated youth of Quebec, and the scene of midnight orgies and profligacy of the worst description, until the extent of the evil attracted the attention of the police authorities, who took measures to repress the mischief.'[4] Since, under the combined influence of religious preaching and of better social environment, they have gradually improved in self-restraint and self-respect. Illegitimate births are now of rare occurrence. Many, however, are still addicted to liquor.

[1] Champlain, iv. p. 85. [2] *Ibid.*, iv. pp. 82–5.

[3] *Jesuit Relations*, passim; Charlevoix, *Journal*, p. 82; *Documents Nouvelle-France*, p. 24; Franquet, *Journal de Voyage*, p. 143.

[4] *Journals Assembly*, 1844–5, Appendix; *ibid.*, 1847, Evidence of Rev. L. Fortier, missionary.

Very little, indeed, remains of the old Huron traditions. The tenets of the Catholic faith have stamped out the pagan myths and superstitions of primitive times. While these Hurons have not attained a very high degree of religious development, they have drifted far away from the beliefs of their ancestors. The only trace—and a doubtful one at that—I could find of their past faith was the vain boasting of one of their old men, who wished to impress me with his medical skill: he had the power, he told me, of stopping or quickening at will the flow of the blood through the sick man's body. Was this a faint recollection of the old-time medicine man and sorcerer?

The Huron tongue is no longer spoken at Lorette. French has replaced it. Even the older members of the tribe, in answer to my inquiries, had the greatest difficulty in recalling a few disconnected words. Some of them could barely tell the meaning of their own Huron name which on exceptional occasions they affix to their every-day French name. Even the few Huron words thus preserved in their family nomenclature do not appear to be rightly pronounced by them; in many names the letter 'L' has been introduced, and this their ancestors did not make use of. For instance, hahn-yohn-yeh, the old Wyandot word for bear,[1] has been changed at Lorette to hahn-yohn-len; Owawandaronhé, Odiaradheité, and Téachéandahé[2] have become respectively Wawendarolen, Ondiaralété, and Téachendalé. As far back as fifty years ago, the Huron tongue was already out of general use at Lorette.[3] From Franquet we learn that about the middle of the eighteenth century a number of the Hurons could speak French.[4]

The Huron boys and girls show marked aptitudes for commerce, industrial arts, and even the fine arts; but they seldom develop these talents to any degree, though opportunities are sometimes offered them of doing so. They nearly all have fine voices and a good ear for music; some of them have shown taste as draughtsmen or painters. The greater number, however, lack the steadiness of purpose which would be necessary to make the most of their talents.

Mode of Living.

As regards food, shelter, clothing, hygiene, recreations, the people of Lorette may be considered to-day as having the same habits as the French Canadians of corresponding classes.

The greater quantity of the food consumed by them is obtained from itinerant traders or from dealers who supply the French Canadians of St. Ambroise as well. I happened to take a meal at the home of one of the poorest Huron families settled on the reserve, and still remember how I enjoyed that simple lunch of milk, butter and bread, cream and preserved fruit, which was daintily served in clean china or glass and on neat linen. From the accounts left by Kalm (1749) and Franquet (1752) we may safely draw the conclusion that, about the middle of the eighteenth century, after one hundred years' intercourse with the French, the Hurons, as regards the food consumed and its preparation, retained much of the tastes and coarseness of their primitive ancestors.[5]

The houses at Lorette are generally small, low-roofed, wooden build-

[1] Connelly, *op. cit.*, p. 103. [2] *Journals Assembly*, 1819.
[3] *Report of Special Commissioners*, 1856, p. 30. [4] Franquet, p. 143.
[5] Kalm, p. 124; Franquet, p. 141.

ings whitewashed. They are disposed in double rows, along narrow lanes, and most of them devoid of yard, garden, or outbuildings. Sometimes these houses are too close to one another for the comfort of their occupants. On the other hand there is an air of cleanliness about them, and with few exceptions, they appear to be as well kept as the tidiest French Canadian farmer's or mechanic's home. The Hurons gave up their old style of long narrow huts made of bark and saplings, and took to building, after the manner of the early French settlers, log and board houses, shortly after their removal (the last in the series) to Jeune Lorette, that is between the years 1700 and 1720.[1] Kalm, in 1749, found them living in houses comprising each two rooms (kitchen and bedroom), but very scantily furnished, so much so that the beds were left without sheets or covering. The Hurons at night were content with wrapping themselves up in the blankets they had worn all day. They were provided with stoves, says Franquet, but the heat they supplied only served to render unbearable to all but Indians the filthiness of the surroundings.[2]

The clothing in use by the Hurons of Lorette is the same as that of the French Canadian working classes. The old Huron style of dress, even that of the later period, has been abandoned. I was able to discover one member only of the band, a Huron lady in the nineties, who still retained the traditional costume of the last century: the short skirt, with the 'mitasses' (leggings) and the moccasins. The costumes in which the 'warriors' and chiefs parade on exceptionally solemn occasions, are almost wholly artificial in their make-up. Ordinary cloth and printed calicoes are used for the purpose, and in the ornamentation of the various parts no trace is seen of the mythical and symbolic forms characteristic of the primitive art of the Huron-Iroquois. Kalm and Franquet, about the middle of the last century, found the Huron women of Lorette still clinging to the old Huron form of dress; but the men, though usually wearing the blanket, at times would don articles of dress borrowed from the French.[3]

Notwithstanding the close grouping of the houses in the village, the hygienic conditions at Lorette are fairly good; a result due in great part to the measures taken by the village council and the people themselves for the sanitation of the surroundings. There has been much admixture of foreign blood. For several generations past the Hurons have intermarried with the whites, principally with the French Canadians. The Huron physical type has been greatly altered, but not entirely blotted out. The massive build and high stature which, we are told, were prevalent features among the old Hurons, are not now common at Lorette; neither are the cheek bones and nose unduly prominent, as a rule; but the rather dark olive complexion, the almond-shaped eyes, and the stiff flat hair are often observed, and perhaps more so in very young children than in the grown-up people.

The amusements indulged in are largely the same as those of the French Canadians in the neighbourhood. A typical initiative on the part of the young men of Lorette was the organising among themselves and equipping of a brass band. The numerous dances which were still gone through on all great occasions, about the middle of the last century,[4] have long since been forgotten. Shooting the arrow was a favourite sport with

[1] Charlevoix, *op. cit.*, p. 83.
[2] Kalm, p. 123; Franquet, p. 144.
[3] Franquet, pp. 140, 141, 144; Kalm, p. 123.
[4] Franquet, p. 143.

the Huron boys, even up to the early years of the nineteenth century. No more is seen of it now. Even lacrosse, the Huron national game, which has become the favourite sport of so many Canadians, is no longer played at Lorette.

Village and State.

Lorette is not well provided with the elements which give variety and activity to village life, and help to build up the framework of municipal government. The employers of labour are very few, and nearly all outsiders, French or Scotch Canadians. In the same way the bulk of the trade which is done at Lorette in connection both with the provisioning of the families and the output of their industries (the smaller class of Indian fancy wares excepted) is carried on by their white neighbours of St. Ambroise.

There is, however, a very notable departure from this condition of things in the enterprise shown by Mr. Maurice Bastien, of Huron descent, who operates the largest hide-dressing and moccasin and snowshoe-making establishment in and about Lorette, and at times gives employment to some fifty people. In other respects also does Mr. Bastien set a good example for his kinsmen to follow. He is almost a total abstainer from alcoholic beverages. He has bought and partly cleared and improved some fifty arpents of land adjoining the village plot, on which he now cuts every year about 20 tons of hay, reaps about 150 bushels of oats and buckwheat, pastures nine cows and some horses. An interesting experiment which he is carrying on for the firm of Renfrew, fur dealers, of Quebec, is the breeding of buffaloes from stock obtained in the State of New York. Mr. Bastien proposes to have one or two of his sons to take up agriculture as a means of livelihood. A further proof of his spirit of enterprise and progress is the building, at his own expense, of a system of waterworks whereby each family in the Huron village is enabled to secure in its own house, at the low rate of four dollars per annum, an abundant supply of pure water.

Education does not provide more leaders than do industry and commerce. The school for girls and that for boys are each under the care of a female teacher paid by the Canadian Government. The school house is built on the site, and partly out of the material of the priest's house erected by the Jesuits in the early years of the eighteenth century. The progress at school of the girls is said to be satisfactory, that of the boys not so. There are very few persons of culture, or even ordinary education, at Lorette. The professional men whose services may be required all reside in neighbouring villages. Mr. Paul Picard, a retired Civil Service employé of the Quebec Government, and the son of a noted Huron chief, resides here. He was employed as a draughtsman, and at one time was a public notary. He is particularly well informed on the history of the Huron community, and a staunch defender of the rights of his kinsmen.

A feature of Lorette is its quaint little church, the greater part of which dates back to 1730.[1] There is no resident missionary, but the parish priest of St. Ambroise, near by, ministers to the religious welfare of the Huron community. An early morning service is held every Sunday and a sermon preached. The singing and preaching are done in French. The

[1] L. St. G. Lindsay, *Revue Canadienne*, 1900, p. 122.

priest receives an allowance of 225 dollars from the Canadian Government for his services in this connection.

Five chiefs (one head chief and four second or sub-chiefs) manage the public affairs of the Huron community under the supervision of the Department of Indian Affairs. These chiefs in council frame regulations for the maintenance of order, the repression of intemperance and profligacy, the care of public health, the construction and repairs of school houses and other public buildings, the locating of land on the reserve, &c. They are elective, and their term of office is for three years.

The above system of government is not the traditional one of the Hurons. It was introduced in recent years by the Canadian Government under the provisions of the Indian Act.[1] In former years the Hurons elected six chiefs or more: one grand chief, one second chief, two council chiefs, and two chiefs of the warriors. These chiefs were elected for life. If we go still further back, to the seventeenth century, we see that the ancient Hurons had many chiefs; war chiefs and chiefs entrusted with various administrative functions; and all were to a certain extent hereditary and to a certain extent elective.[2]

At the present time the head chief of the Hurons of Lorette (elected quite recently) is François Gros-Louis. Maurice Bastien, Gaspard Picard, Maurice Tsioui are three of the sub-chiefs.

The Hurons of Lorette are under the tutelage of the State. Their landed property is held in trust for them by the Department of Indian Affairs. The latter also has the management of the revenue derived from part of these lands, and out of which expenses of a public character are to be paid. The Department is kept informed, and generally acts through an agent, who resides on the reservation—Mr. A. O. Bastien, an intelligent and educated Huron.

There has been of late years much dissatisfaction and strife in the Huron community over the management of public affairs. A party, consisting chiefly of a large number of the Tsiouis, think they have not had their proper share of the funds. They find fault with the chiefs, the agent, and the Department as well. They refuse to attend meetings, to take part in elections, and are intent on electing chiefs of their own.

A remarkable fact is that the Hurons as a whole show no desire of being enfranchised. Even the malcontents scorn the idea. Under present conditions the Government meets all expenses in connection with church and school and other matters. Practically they have no taxes to pay, not even roads to maintain, the way-leave over the reserve being granted to residents of neighbouring parishes on condition that they take charge of the road. Enfranchisement, they say, would only add to their burdens and render them more liable to be swindled out of their property by the more unscrupulous of their white neighbours.

Before concluding, it will be of interest to make a rapid review of the influences which, acting on the primitive Huron type, brought it to its present stage of social transformation. These influences may be classed under three heads: (1) Early trade relations with the French and preaching of the Gospel; (2) physical features of the country about and back of Quebec; (3) close neighbourhood and competition of the white settlers.

[1] Revised Statutes of Canada, cap. 43, sects. 75 and 76.

[2] Brébeuf, *Jesuit Relations*, Thwaites's edition, vol. x. pp. 231, 233; Parkman, *Jesuits in North America*, Introduction, p. lii.

1. The first series of influences (commercial intercourse and religious preaching) exerted themselves over the ancient Hurons previous to their leaving their old abode in Western Ontario. Commerce introduced into the Huron villages by the early French discoverers, or, at least, greatly developed by them, upset the balance of the traditional system of labour of the Hurons, by reducing the relative importance of agriculture as a means of livelihood for them. Thereby the Hurons were rendered less sedentary, more nomadic, less apt to fortify their villages and to hold the country against invaders. The young and able-bodied men were kept much away from home by their hunting and trading expeditions, leaving the towns insufficiently protected against attack, while themselves heavily laden with furs or other goods, but scantily equipped with arms and ammunition, fell an easy prey to Iroquois war parties.

Again, commerce, by reducing the importance of agriculture in the labour system of the Hurons, weakened the clan organisation, on which the whole Wyandot social fabric rested. Female clanship was dependent for its strength on the social prestige of the women; and this in turn was largely dependent on the development of agriculture, which was left to their charge.[1] The preaching of the new religious dogmas by the Recollet and Jesuit missionaries and the conversion to the faith of a number of the Hurons also tended to undo the binding action of clanship. For clanship in its origin was blended with the religious beliefs of these primitive people; each clan was under the special protection of a pagan myth, and the preaching of the Gospel released the hold which these myths had on the minds of the Hurons. In that way were the strong family ties which bound together the scattered parts of the Wyandot confederacy loosened, and the Hurons rendered less capable of strong united action. In that way were the Iroquois enabled to defeat one after the other the disconnected groups and bring about the utter dispersal of the Huron nation. Such is the social significance of the facts set forth in the early accounts.[2]

Of the five or six tribes, or subordinate nations, which made up the Wyandot confederacy, only three (the nation of the Bear, that of the Rock, and that of the Rope) repaired towards Quebec. A few years later two of these tribes were forced by the Mohawks and the Onondagas to join their respective nations; and the nation of the Rope was finally the only one to remain with the French.[3] From this sole tribe, very much disorganised and reduced in numbers, and still further reduced by subsequent wars, did the present Lorette community spring.

2. The physical features of the country about and back of Quebec, characterised by the restricted area of the arable belt and the development of the mountain and forest tract, had the effect of keeping the small Huron group away from agriculture, of turning it more completely towards the chase and those industries dependent on the chase and the forest for their raw material. Thereby the Hurons were prevented from acquiring any greater fitness for heavy and steady labour, and from developing any greater ability or desire to hold land.

3. The close neighbourhood and competition of the white settlers had two quite distinct effects on the Hurons. On the one hand, their influence

[1] P. de Rousiers, *La Science Sociale*, 1890, vol. x. p. 141.

[2] Champlain, iv. pp. 43, 44, 101; *Jesuit Relations*, Quebec edition, 1642, pp. 55, 56; Charlevoix, vol. i. p. 201.

[3] *Jesuit Relations*, 1657, pp. 20 and 23.

united with that of physical environment in checking the agricultural development of the Hurons and retaining them in the lower forms of labour and property. On the other hand these conditions of close intercourse with the white settlers—brought about by the reduced area of the Lorette holdings—transformed the home-life, and in the end materially improved the entire mode of living, of the Hurons.

The Iroquois community, settled at Caughnawaga, in the vicinity of Montreal, provides an interesting subject of comparison; for, though originally of the same social type as the Hurons, their evolution in recent times has been in quite the opposite direction.

In conclusion, the greatest weakness in the social organisation of the Hurons, and the one which should be remedied first, is that resulting from their property conditions. An ever-recurring theme of conversation among young and old at Lorette is the endless series of their grievances, all more or less connected with property rights: grievances against the Jesuits for having dispossessed them, or allowed them to be dispossessed, of their seigniory of Sillery; grievances against the British Government for not having restored them to their rights after the conquest; grievances against some of their deceased chieftains, for having laid hands, so they declared, on parts of the common land; grievances also against some of the present chiefs for using the common property for private ends; grievances against the Provincial Government for invading their hunting grounds; and, finally, grievances against the Federal Government and its agent for alleged maladministration of the reserves and the revenues therefrom. The limited extent and collective ownership of the holdings have had the effect, not only of helping to keep the Hurons away from agriculture and bringing about over-density of population in the village, but also of concentrating the minds and energies of individuals on petty common rights and privileges (to the detriment of initiative in more fruitful pursuits) and of breeding a harmful spirit of discontent.

It seems that much would be done for the betterment of the condition and the more normal development of these Hurons were it found possible to carry out the plan suggested by Sir James Kempt as far back as 1830, and further recommended by the Government Commissioners in 1847; that is, if land in the vicinity of Lorette and suitable for agriculture were, on proper terms, put at the disposal of the Hurons, on which some of them at least, under intelligent and kindly supervision, might be made to acquire proficiency in farming and aptness for the management of property. Thus would they become a less dependent, a more contented and prosperous community.

Anthropological Photographs.—Interim Report of the Committee, consisting of Mr. C. H. Read (*Chairman*), Mr. J. L. Myres (*Secretary*), Mr. H. Balfour, Professor Flinders Petrie, Dr. J. G. Garson, Mr. E. S. Hartland, *and* Mr. H. Ling Roth, *appointed for the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.*

The Committee report that a considerable number of photographs have been collected and registered; but that it has been found advisable to postpone till next year the publication of a reference list. The Committee ask to be reappointed.

Fertilisation in the Phæophyceæ.—Report of the Committee, consisting of Professor J. B. FARMER (*Chairman*), Professor R. W. PHILLIPS (*Secretary*), Professor F. O. BOWER, *and* Professor HARVEY GIBSON.

THE Committee learn from Mr. J. Lloyd Williams, to whose assistance they have again devoted the whole of the grant of 20*l.* placed at their disposal, that during the past year he has investigated the following subjects :—

1. The germination of the zoospores has been studied in *Laminaria*, *Alaria*, and *Chorda*. Some interesting additions have been made to our knowledge of reproduction in the Laminariaceæ, and particularly of the cytology of the process. Incidentally the medullary tissues of the above and of other genera of the family have been studied.

2. The life-history and cytology of *Dictyota* have been further studied. Additional notes will be presented to the meeting of the Association, and the full results will be published during the winter. *Taonia*, *Padina*, and *Haliseris* are being studied for comparison.

3. The study of the life-history and cytology of *Halidrys* has been completed, and the results are awaiting publication. The cytology of the reproductive process in *Himanthalia* and *Cystoseira* is being investigated.

4. The natural history of the Fucaceæ has been further studied, and it is hoped to publish the observations before the end of the year.

5. The study of the nuclei of the reproductive cells of the Ectocarpaceæ has been commenced, with a view of ascertaining whether there is reduction of chromosomes at any stage.

6. Cultures of nearly all of the above are carried on in the laboratory, and careful record kept of their relation to light, heat, air, and pressure.

Your Committee are of opinion that Mr. Williams is doing excellent work, and that the grant has been wisely used.

Mr. Williams hopes to bring some of his observations on the germination of the zoospores of Laminariaceæ before the notice of the Section at Bradford.

Assimilation in Plants.—Report of the Committee, consisting of Mr. F. DARWIN (*Chairman*), Professor J. REYNOLDS GREEN (*Secretary*), *and* Professor MARSHALL WARD, *appointed to conduct an Experimental Investigation of Assimilation in Plants.*

THE Committee beg leave to report that the remainder of the grant of 20*l.* made at Bristol in 1898 has now been practically expended on

apparatus for aiding Mr. Blackman in the continuation of his researches on Vegetable Assimilation and Respiration.

Enough progress has been made in various directions to allow of the results being brought forward, and the author is engaged in preparing them for publication. The first to appear will be those treating of (1) the influence of the available amount of plastic substances on respiration; (2) the exact relation of respiration to temperature; and (3) the relation between water-content and assimilation.

Corresponding Societies Committee.—Report of the Committee, consisting of Professor R. MELDOLA (*Chairman*), Mr. T. V. HOLMES (*Secretary*), Mr. FRANCIS GALTON, Dr. J. G. GARSON, Sir JOHN EVANS, Mr. J. HOPKINSON, Mr. W. WHITAKER, *the late* Mr. G. J. SYMONS, Professor T. G. BONNEY, Sir CUTHBERT PEEK, Dr. HORACE T. BROWN, Rev. J. O. BEVAN, Professor W. W. WATTS, *and* Rev. T. R. R. STEBBING.

THIS being the last year of the century, the Corresponding Societies Committee of the British Association think it a suitable occasion for a brief review of the proceedings which have taken place at the Conferences of Delegates of the Corresponding Societies since they were reconstituted in the year 1883. The Report of the 'Local Scientific Societies Committee,' stating that 'the delegates of the various Corresponding Societies shall constitute a Conference,' &c., appears in the Report of the British Association for 1884; the first Conference of Delegates officially recognised as a department of the Association was held at Aberdeen in 1885, and a report of its proceedings is given in the Birmingham volume (1886).[1] Thence to, and including, the year 1893 the Reports of the Conferences are one year behind. Thus the discussions at the Edinburgh meeting in 1892 are given in the Nottingham volume of 1893. But in the Oxford volume (1894) appear Reports of the Conferences held both at Nottingham and at Oxford; and since 1894 the Reports of the Conferences of Delegates may be found in the Report of the British Association for the year in which they occurred. The chief subjects considered at the Conferences are here given, ordinary sectional discussions being noticed when they were the only discussions of the Conference.

Year and Place	No. of Delegates nominated	Chief subjects discussed
1885. Aberdeen .	24	Methods of procedure, and on the nature of the work which admitted of being taken up by local societies
1886. Birmingham	32	On the objects of the Conference, and the ways in which the local societies could most usefully co-operate with British Association Committees

[1] The first report of the Corresponding Societies Committee was presented at Aberdeen and is given in the Report for 1885, pp. 708–722.

TABLE—*continued.*

Year and Place	No. of Delegates nominated	Chief subjects discussed
1887. Manchester	32	On the recommendations received from the various Sections. It was announced that a Resolution passed in 1887 by Sections B and C—'That the Conference of Delegates of Corresponding Societies be empowered to send recommendations to the Committee of Recommendations for their consideration and for report to the General Committee'—had been accepted by the General Committee, and had become a rule of the British Association
1888. Bath .	38	The Ancient Monuments Act
1889. Newcastle-on-Tyne	35	On the placing of Delegates on Sectional Committees. The following Resolution was passed:—'That the relations of delegates to the Sectional Committees as at present existing are unsatisfactory, and that the matter be referred to the Corresponding Societies Committee for their consideration.' The Committee reported that 'after giving the matter careful consideration they have come to the conclusion that they possess no power under the present rules of the Association of attaching delegates to the Sectional Committees'
1890. Leeds .	36	On the desirability of bringing the smaller non-publishing local societies into relationship with the British Association. The Corresponding Societies Committee authorised its Secretary 'to supply any local society which may apply for them with copies of the reports of the Conferences, the lists of Committees, and other information likely to be of use in furthering local scientific investigation'
1891. Cardiff .	36	Various subjects connected with Sections A, B, C, D, E, G, and H
1892. Edinburgh .	42	The destruction of native plants and of the eggs of wild birds
1893. Nottingham	39	Subjects considered in Sections A, C, D, E, G, H
1894. Oxford .	41	The organisation of local museums
1895. Ipswich .	33	Meteorological observations and records
1896. Liverpool .	49	District unions of natural history societies. On a federal staff for local museums
1897. Toronto .	24	The federation of local societies. The life-histories of animals. Principal museums in Canada and Newfoundland
1898. Bristol .	46	Coast erosion. The desirability of uniformity of size in the pages of the publications of scientific societies
1899. Dover .	37	The living subterranean fauna of Great Britain and Ireland. The objects of the 'National Trust for Places of Historic Interest or Natural Beauty.' And as to the best means of making the Conferences of Delegates more useful

As stated in the Report of the Dover Conference, it was decided that with regard to the best ways of making the Conferences more useful the

Delegates should forward their views on the subject to the Corresponding Societies Committee for consideration at their meeting in November; and as some Delegates were not present during the discussion, copies of the following letter were sent to every Delegate nominated to the Dover Conference:—

British Association, Burlington House, London, W.,
October 5, 1899.

DEAR SIR,—At the second meeting of the Conference of Delegates at Dover, September 19, a discussion took place as to the best means of improving the proceedings at these meetings. It was ultimately decided that any recommendations from the Delegates on that matter, if sent in not later than November 7, would be considered by the Corresponding Societies Committee at their meeting later in that month.

I am, dear Sir,
Yours truly,
T. V. HOLMES,
Sec. Cor. Soc. Com. Brit. Assoc.

When the Corresponding Societies Committee met on November 24, 1899, twelve replies to the above letter had been received from the representatives of fourteen societies; and in March 1900 some additional recommendations were received from the Yorkshire Naturalists Union.

The various suggestions mostly deal either with proposed alterations in the times of meeting, with the desirability of a room in which Delegates might hold informal discussions between the meetings of the Conference, or with improvements in the proceedings at the Conference.

As regards the days and hours on which the Conferences have hitherto been held, the Committee found it so difficult to suggest any others which might not prove to be accompanied by still greater disadvantages that they have refrained from proposing any alteration in them.

The Committee considered it not desirable to propose to alter the rule of the British Association that only members, not associates, can become Delegates.

The Committee agreed that it is desirable when possible that a room shall be provided at the Bradford and other future meetings of the Association, in which Delegates may meet, become acquainted with each other, and hold informal discussions between the meetings of the Conference.

As regards a suggestion that an agenda paper should be sent to the Corresponding Societies some time before the British Association meeting in order that Delegates might come better prepared to the Conference, it was decided that although the circular issued in July is *inter alia* an agenda paper, it would be well to add a clause to it asking that the Secretary of each Corresponding Society receiving it should bring the subjects for discussion at the Conference before the notice of the Delegate of the Society.

It was also decided by the Committee that the circular drawn up some years ago by Dr. Garson stating the rules respecting the Corresponding Societies and the advantages granted to them should be reprinted and sent to the Corresponding Societies in March; and that at the same time a notice should be sent inviting the Societies to consider what

subjects they wish to have discussed at the next Conference of Delegates, and fixing a date by which suggestions must be sent.

The following Societies have been added to the list of Corresponding Societies :—

1. The Birmingham and Midland Institute Scientific Society.
2. The Eastbourne Natural History Society.
3. The Natural History Society of Northumberland, Durham, and Newcastle-on-Tyne.
4. The Hull Scientific Society and Field Naturalists' Club.

Report of the Proceedings of the Conference of Delegates of Corresponding Societies held at Bradford.

The Council nominated Professor E. B. Poulton, Chairman, Mr. W. Whitaker, Vice-Chairman, and Mr. T. V. Holmes, Secretary, to the Bradford Conference. These nominations were confirmed by the General Committee at a meeting held at Bradford on Wednesday, September 5. The meetings of the Conference were held in a room in the Grammar School, adjoining the Reception Room, on Thursday, September 6, and Tuesday, September 11, at 3 p.m. The following Corresponding Societies nominated as delegates to represent them at the Bradford meeting—

Belfast Naturalists' Field Club . . .	William Gray, M.R.I.A.
Belfast Natural History and Philosophical Society	John Brown.
Berwickshire Naturalists' Club . . .	G. P. Hughes.
Birmingham and Midland Institute Scientific Society	W. Bayley Marshall, M.Inst.C.E.
Birmingham Natural History and Philosophical Society	Chas. Pumphrey.
Buchan Field Club	John Gray, B.Sc.
Cardiff Naturalists' Society . . .	Walter Cook.
Croydon Microscopical and Natural History Club	W. Whitaker, F.R.S.
Dorset Natural History and Antiquarian Field Club	Vaughan Cornish, M.Sc., F.R.G.S.
Essex Field Club	Professor E. B. Poulton, F.R.S.
Glasgow Geological Society . . .	J. Barclay Murdoch.
Glasgow Natural History Society . .	J. F. Gemmill, M.D.
Glasgow Philosophical Society . . .	Prof. A. Barr, D.Sc.
Hertfordshire Natural History Society .	J. Hopkinson, F.L.S.
Hull Geological Society	J. W. Stather, F.G.S.
Hull Scientific and Field Naturalists' Club	T. Sheppard, F.G.S.
Institution of Mining Engineers . .	Professor Henry Louis, M.A.
Isle of Man Natural History and Antiquarian Society	J. Lomas, F.G.S.
Leeds Geological Association . . .	D. Forsyth, M.A., D.Sc.
Liverpool Geographical Society . .	Staff-Com. Dubois Phillips, R.N.
Malton Field Naturalists' and Scientific Society	M. B. Slater, F.L.S.
Manchester Geographical Society . .	Eli Sowerbutts, F.R.G.S.
Manchester Geological Society . . .	Wm. Watts, F.G.S.
Manchester Microscopical Society . .	F. W. Hembry, F.R.M.S.
Midland Institute of Mining, Civil, and Mechanical Engineers	John Gerrard

Norfolk and Norwich Naturalists' Society	Clement Reid, F.R.S.
North of England Institute of Mining and Mechanical Engineers	M. Walton Brown.
Northumberland, Durham, and Newcastle-upon-Tyne Natural History Society	Professor M. C. Potter, F.L.S.
Nottingham Naturalists' Society . .	Professor J. W. Carr, F.L.S.
North Staffordshire Field Club . . .	R. Hornby, M.A., F.C.S.
Perthshire Society of Natural Science .	A. M. Rodger.
Rochdale Literary and Scientific Society .	J. R. Ashworth, B.Sc.
Rochester Naturalists' Club . . .	Dr. G. Abbott.
Scotland, Mining Institute of . . .	James Barrowman.
South-Eastern Union of Scientific Societies	Rev. T. R. R. Stebbing, F.R.S.
Woolhope Naturalists' Field Club . .	Rev. J. O. Bevan, M.A.
Yorkshire Geological and Polytechnic Society	Wm. Gregson, F.G.S.
Yorkshire Naturalists' Union . . .	Harold Wager, F.L.S.

First Conference, Bradford, September 6, 1900.

The Corresponding Societies Committee were represented by Prof. E. B. Poulton (Chairman), Rev. J. O. Bevan, Dr. Garson, Mr. J. Hopkinson, and Mr. T. V. Holmes (Secretary).

The Report of the Corresponding Societies Committee, a copy of which was in the hands of every Delegate present, was taken as read.

The Chairman remarked that all present must have received the agenda paper, and have noted that the subject for discussion that day consisted of two resolutions which had been brought forward by the Yorkshire Naturalists' Union. In the Report then circulated there were comments bearing on the subjects of these resolutions which the Committee wished should be discussed thoroughly on that occasion.

The resolutions were :—

1. That the Conference of Delegates be allowed to meet on the first day of the British Association Meeting, and make their own arrangements for subsequent meetings and order of business.

2. That it is desirable, in order to make the discussions of the Conference of Delegates more useful to the local Societies, that they should have the power of deciding the subjects for discussion at the meetings of the Conference, and it is suggested, therefore, that a circular be sent by the Committee every year to each of the Corresponding Societies, asking them to send a list of subjects for discussion (not more than two or three) at the forthcoming meetings. The Committee then to send to the Corresponding Societies a schedule containing the titles of all the subjects proposed for discussion, asking each Society to mark such of these subjects as it deems most desirable to discuss at the Conference meetings. On receipt of this information the Committee will then arrange the list of subjects in order of precedence as indicated by the support given to each subject by the Societies ; and a copy of this should be sent to the Delegates or Societies as an agenda paper before the first meeting of the Delegates.

Mr. Harold Wager, representing the Yorkshire Naturalists' Union, which comprises a large number of local Societies, said that the Union had called together a committee consisting of a number of their more prominent members, and they had formulated the two resolutions, copies of which had been distributed. It was considered most important that the representatives of the local Societies should, if possible, themselves

suggest the subjects for discussion. Much good work had been done at these Conferences, but those whom he represented thought that if direct suggestions from the local Societies were invited, the wants of the Societies would be more advantageously considered than they had been in the past, and that they would come into closer touch with each other.

Staff-Commander Dubois Phillips, R.N., thought that the resolutions somewhat contradicted each other. According to the first resolution, the Delegates were to meet on the first day of the meeting of the British Association, and make their own arrangements for subsequent meetings; and the second resolution laid down hard and fast lines with regard to the subjects for discussion and their order. The opinion of the Council of the Society he represented was that Delegates should not come there to discuss subjects such as could be discussed in the various Sections, but that the Conferences should rather be business meetings to consider questions such as that of copyright. It would be a very good thing to ascertain the views of the various Societies as to the best subjects for discussion. He thought that if the first Conference took place on the first day of the British Association meeting very few Delegates would be present at it.

Mr. J. Hopkinson said that many of the proposals contained in the resolutions had already been carried out. Last March a circular was sent to each Corresponding Society asking it to send to the Corresponding Societies Committee a list of subjects for discussion at the Bradford Conference. Why, therefore, should there be a resolution stating that this should be done? Only one Society had responded to this invitation by suggesting a subject for discussion. And Mr. T. V. Holmes added that the one subject sent in (Dew-ponds) would be discussed at the second Conference.

Mr. Hopkinson remarked that the first day of the British Association meeting would be an exceedingly awkward time for the first Conference on account of the meeting of the General Committee, and of the delivery of the President's Address on that day. And not only was that day impracticable for the first Conference, but it would also be impossible to arrange then what should be done subsequently. Arrangements of this kind must be made months beforehand. In his opinion the first resolusion was impracticable, while, as regards the second, the most important parts of it had already been carried out by the Corresponding Societies Committee.

Dr. Garson said that practically Thursday was the first day of the British Association meeting, and that very few Delegates were ever likely to be present at a meeting on Wednesday. The Corresponding Societies Committee were always glad to get assistance from the Delegates in the choice of subjects for discussion, and the complaint of the Committee had long been that the local Societies did not take a sufficiently active part in such matters.

Mr. G. P. Hughes could not agree with the first resolution, as members often arrived late on Wednesday. He thought some of the stipulations in the second resolution should be adopted.

Mr. William Gray said that the main object of these Conferences was to encourage local Societies so as to make their local arrangements to promote the chief object of the British Association, the advancement of science. The British Association should point out what matters they wished the local Societies to investigate. At the first meeting of the

Conference the British Association Committee should receive a report from each of the Societies, and at the next meeting the Delegates should have an opportunity of making suggestions. At the opening Conference the British Association Committee should learn how far the local organisations were competent to conduct the investigations put before them by the Association. At the second the Delegates should consult among themselves as to the best way in which any deficiencies pointed out at the first meeting might be remedied.

Mr. Eli Sowerbutts remarked that the Delegates had not hitherto had sufficient opportunities of becoming acquainted with each other. He had been a Delegate about fifteen years, and knew, perhaps, four of the other Delegates. It was seldom that the same Delegate came year after year. He thought the simplest thing would be to pass the first resolution and to omit the second, though somewhat doubtful whether the result of passing the first resolution would be of any importance. But he wished a room to be recognised during the meetings of the Association as one in which the Delegates might meet informally, sit, chat, or write their letters between the formal Conferences. The Societies they represented might then combine for mutual assistance, and they, the Delegates, might also more efficiently aid the work of the Association.

Mr. T. V. Holmes wished to call attention to the paragraph at the bottom of the third page of the Report in their hands: 'The Committee agree that it is desirable, when possible, that a room shall be provided at the Bradford and other future meetings of the Association in which Delegates may meet, become acquainted with each other, and hold informal discussions between the meetings of the Conference.' He had to add that the room in which they were then assembled was that in which the Delegates might meet at any time.

Mr. Wager proposed a vote of thanks to the local Committee for providing the room. The motion was seconded by Staff-Commander Phillips and carried unanimously.

Mr. W. Bayley Marshall formally moved that the meetings of the Conference be held as heretofore on Thursday and Tuesday. There would then be fixed days of meeting, and the Delegates could arrange to attend accordingly.

Mr. Hembry seconded the motion. He thought it might be possible for the Corresponding Societies Committee to arrange with other Committees that no important business should be transacted elsewhere during the meetings of the Conference.

The Chairman remarked that they would do their best.

Mr. Hembry added that Delegates did not always receive communications intended for them which were sent to the Secretaries of local Societies. He thought it would be a good plan to send to the Delegate of this year notices referring to next year, because in all probability the Delegate of this year would be selected next year. If not, he could hand on to his successor the papers he had received. He considered that an addition might be made to the second resolution to the effect that a circular be sent every year to each of the Corresponding Societies and to the Delegate of the present year.

A Delegate who had been instructed by his Society to support the resolutions of the Yorkshire Naturalists' Union, supposed that the mover of the resolutions did not mind whether their first meeting was on Wednesday or Thursday. An amendment which he desired to move was

that the first meeting should be on Thursday, and that the Conference of Delegates should then decide themselves the dates of the subsequent meetings.

Professor Henry Louis seconded the amendment.

Mr. Vaughan Cornish thought that business discussions rather than scientific papers were required. Not two, but three, bodies were trying to do business together—the Corresponding Societies Committee, the Corresponding Societies, and the Delegates. His opinion was that it would be well for the Committee to recognise the Delegates rather than the Societies.

Dr. Abbott said that it occurred to him that the Delegates might meet on Thursday morning at a breakfast. There was little probability that any other social function could be arranged. The Committee should encourage the formation of Unions of Local Societies.

Mr. Barrowman favoured the proposition that the Conference at its first meeting should arrange the following meetings.

The Chairman remarked that it was evident that the Conference did not wish to listen to papers such as might be brought before the Sections of the Association. They desired rather to discuss the methods of procedure which would make local Societies successful. The Committee were in general agreement with the spirit of the two resolutions. He gathered from certain remarks which had been made that the local Societies were often to blame for not giving Delegates copies of circulars sent by the Committee to the Secretaries of the Societies long before the British Association meetings took place. The present days for the Conference seemed to be the best that could be chosen, and they had the advantage of being known beforehand. The debate had been most useful in showing the nature of the questions which the Delegates desired to discuss at these Conferences.

Mr. W. Gray said that the local Societies did not do their duties adequately because those duties were not clearly defined by the British Association Committee. He thought that the Committee should ascertain at the first Conference each year how far each Society had acted in accordance with the requirements of the Committee. The proceedings at the second Conference might be settled by the Delegates themselves.

The Chairman remarked that the new questions which had been raised should have been sent in months ago when the resolutions of the Yorkshire Naturalists' Union were received by the Committee. A discussion on them might be initiated under a heading such as 'What are the aims and scope of a local Society?'

Mr. W. Gray thought that the grant of a room in which Delegates might meet at any time was an immense advantage, which might remove altogether the necessity for a second meeting.

Mr. T. V. Holmes (Secretary) stated that in consequence of the discussion at Dover as to the best ways of improving the proceedings at the Conferences of Delegates, he wrote to the thirty-seven Delegates inviting suggestions which could be placed before the Committee a month later, but received answers only from twelve.

The Chairman said that, as he believed, the British Association did not intend that local Societies should work on any special or peculiar lines in relation to itself. The Association wished that local Societies should do local work, and endeavoured to assist them by means of these Conferences, by the exchange of its Report for their Proceedings, and

by publishing in its Report the titles of papers read before and published by the Societies.

Mr. H. Wager, after briefly reviewing the discussion, remarked that though the resolutions had secured a considerable amount of general acceptance, he did not think it desirable to put them formally to the meeting.

The Chairman agreed to this course, which he considered to be the best under the circumstances. He thought that the discussion would prove to be very useful.

Mr. W. Gray proposed, and Staff-Commander Phillips seconded, a vote of thanks to the Corresponding Societies Committee for providing the room in which they were assembled for informal intercourse between the Delegates. It was carried unanimously. The motion proposed by Mr. Bayley Marshall, and seconded by Mr. Hembry, 'That the meetings of the Conference be held as heretofore on Thursday and Tuesday,' was also carried.

Copyright.

Mr. Walton Brown brought forward the question of copyright. Lord Monkswell had introduced into Parliament a Bill dealing with the subject, and, so far as scientific Societies were concerned, the Bill ignored some important points. In the first place there was no provision that a Society should have any copyright in the publication of its own Transactions, though he believed Societies might obtain copyright if they paid their contributors. He had offered to give evidence before the Committee considering this Bill, but the Committee replied that they accepted his evidence, and did not think it necessary to examine him. Then the Bill proposed to make the insertion of abstracts of foreign scientific papers a breach of copyright; an innovation that would weigh heavily on several scientific Societies which made a special point of publishing abstracts.

Mr. Sowerbutts thought that this was one of the most important matters that had ever been discussed at a Conference. Copyright questions were extremely involved, and difficult to understand; but there could be no doubt of the injustice of the present state of things, and that it would be confirmed by the Bill then before Parliament. The expense of printing papers was by no means a slight one.

Professor Henry Louis pointed out that the British Association disclaimed copyright for itself. It was, however, a matter of vital importance to each Society represented at that Conference.

After some remarks from the Rev. J. O. Bevan and the Chairman, the following resolution, moved by Mr. M. Walton Brown and seconded by Mr. Sowerbutts, was carried unanimously:—

'That the matter of the proposed Copyright Bill be referred, through the Committee of Recommendations, to the General Committee, so far as it affects (1) the copyright of scientific Societies in their Transactions; and (2) the publication of abstracts of scientific papers; and that they be requested to take such action as will protect scientific Societies.' [1]

The Conference then adjourned.

[1] The resolution was by an accident not sent to the Committee of Recommendations, but it has been arranged that it shall be brought before the Council for consideration.

Second Meeting of the Conference, September 11.

The Corresponding Societies Committee were represented by Mr. W. Whitaker (Vice-Chairman), Rev. J. O. Bevan, Dr. Horace T. Brown, Dr. Garson, Mr. J. Hopkinson, and Mr. T. V. Holmes (Secretary).

The Chairman briefly introduced Professor L. C. Miall, who read the following Address:—

Dew-ponds. *By* Professor L. C. Miall, *F.R.S.*

I lately undertook a new edition (the 83rd or 84th) of White's 'Natural History of Selborne,' and found it necessary to consider the account of the Hampshire dew-ponds which is to be found in Letter XXIX. to Barrington. 'We have,' he says, 'many such little round ponds in this district, and one in particular on our sheep-down, three hundred feet above my house, which, though never above three feet deep in the middle, and not more than thirty feet in diameter, and containing perhaps not more than two or three hundred hogsheads of water, yet is never known to fail, though it affords drink for three hundred or four hundred sheep, and for at least twenty head of large cattle beside.' This account, of which I quote one sentence only, led me to inquire a little into this curious subject by correspondence, by reference to the rather scanty literature which already exists, and by personal visits. My inquiries are, I must admit, very imperfect, but they may be the means of inducing people whose opportunities are better than mine to collect fuller information.

White's account of the dew-ponds of Hampshire is largely confirmed by more recent observation. A good description of such ponds is to be found in a prize essay on 'Water Supply,' by the Rev. J. C. Clutterbuck. He says that the tops of chalk hills, where no surface-water or springs can furnish a supply, are often chosen as the sites of dew-ponds. They 'are constructed by persons of experience and skill. At the spot selected an excavation is made in the surface of the chalk, either round or rectangular, from thirty to forty feet or more in diameter, from four to six feet deep. The bottom, of a basin shape, is covered in portions with clay carefully tempered,[1] mixed with a considerable quantity of lime to prevent the working of the earthworms.[2] As the portions are finished they are protected from the action of the sun and atmosphere by a covering of straw. When the whole bottom of the pond is so covered with an efficient and impermeable coating or puddle a layer of broken chalk is placed upon it to prevent its injury by cattle or other means. Their cost varies from 30*l.* to 50*l.* When all is finished water is introduced by artificial means. If there is a fall of snow this is collected and piled up in the pond as the readiest and least expensive method of accomplishing the object. . . . Ponds so constructed and filled have been known for periods of twenty or thirty years never to become dry. The summer of 1864 was a notable exception.'

Dew-ponds are often dug on the very ridge of a down, or else by choice on the northern slope, which is the inland slope in most of the

[1] Chalk-puddle is occasionally used instead, but is believed to be less efficient and less durable.

[2] It may be doubted whether the purpose of the lime is to prevent the working of earthworms, which cannot live beneath a pond. It is an old practice to spread wet clay with lime in the belief that it prevents slipping.

south-eastern counties. It is generally held that moist winds throw down their water most abundantly just beyond the summit of the first range of hills which they meet. In the case of the downs of Hampshire and Sussex the inland slope has the further advantage of being sheltered from the sun and all the warmer winds, so that it is the fitter for the condensation of water-vapour.

Mr. Clutterbuck believes that dew-ponds are 'not easily accounted for by recognised physical causes.' It is plain that the water which collects on the summit of a chalk-down is not drawn from springs, for the saturation-level is hundreds of feet below. Nor is it due in any important measure to surface-drainage. A small collecting area is furnished by the margin of the pond, but this rarely equals the water-surface. A dew-pond may occupy the summit of the ridge so precisely that there can be no collecting ground worth speaking of.

Hales's view (quoted by White) that more than twice as much dew is deposited upon water as upon an equal surface of moist earth cannot be accepted as it stands. He does not take into account circumstances which may greatly affect the rate of cooling, and consequently the amount of condensation, such as the depth of the water. It may often be observed, for instance, that when a copious dew has been deposited upon the seats of an open boat none is to be seen on the bottom. Contact with a large body of insufficiently cooled water (as of a deep lake) has kept the bottom of the boat at a temperature above the dew-point.

Water is so bad a conductor of heat that some difficulty may be found in understanding how a pond can cool sufficiently during a summer night to act as an efficient condenser. But though water conducts heat very badly, every surface layer, as it cools by radiation, becomes denser, and sinks. Continual replacement of the surface layer by convection-currents may thus cool down the water as effectually as if the heat were freely conducted away. A shallow pond on a hill-top may in the course of a few hours become cold enough to act as an efficient condenser.

Water vapour, liquid water, and ice are all good absorbents of dark heat-rays; it may be inferred that they are good radiators of dark heat-rays. This perhaps does not admit of experimental proof. The radiation from water in a pond is complicated by so many circumstances, such as the absorption of heat by the water vapour which the pond gives off, and the sinking of the water as it cools, that no determination by direct methods is possible.

There is a good deal of testimony to the effect that a dew-pond prospers best with a depth of about 4 feet. If it is deeper it shrinks to such depth as will cool down during a short summer night, *i.e.* about 4 feet; if it is much shallower it dries up altogether in a drought. This account, though probable in itself, needs to be scrutinised further. I know as yet of no facts to the contrary, and several in its favour.

Dew-ponds abound in Sussex and Hampshire, and are not uncommon on the chalk hills of Berkshire and Wiltshire. But on the chalk hills of Hertfordshire, Bedfordshire, Lincolnshire, and Yorkshire few or none are to be found. This may be connected with the distance from the sea in a N.E.-S.W. line. The S.W. winds, which bring the chief part of our atmospheric moisture, can reach the South Downs almost direct from the sea, while they can only reach the chalk hills of the Midlands and the North of England after traversing a great extent of country and crossing many ranges of hills.

The few that have been mentioned to me as occurring in the Midland counties all turned out on inquiry to depend obviously on surface drainage, usually from a hollow in a neighbouring hard road. It is thus with the 'meres' of Derbyshire which appear, from such information as I have been able to procure, to be always fed from adjacent collecting grounds. If any one can furnish an unexceptionable example of a true dew-pond on a chalk-down, or other hill, which is distant a hundred or even fifty miles from the south coast, the news would be welcome.

Those who believe that dew-ponds in all cases owe their existence to rainfall alone (and among these was that eminent meteorologist, the late G. J. Symons, F.R.S.) hold that, owing to elevation, the temperature of the water in such ponds is very nearly coincident with the dew-point, so that evaporation and condensation balance each other. Whether such a temperature of the water is regularly maintained day and night throughout a season of drought cannot, I believe, be established by existing thermometric observations. I doubt whether it can be established by general reasoning. Before we can accept the view that dew-ponds are replenished by rain alone, we must refute or explain two facts, both of which are supported by strong testimony :

1. That dew-ponds do not dry up when the low-level ponds of the same district are evaporated. Not only do the dew-ponds replace in some way the loss due to evaporation, but they supply large flocks of sheep. If it is contended that during summer droughts the hill-tops are regularly visited by local clouds which are precipitated as rain, the frequency and substantial yield of such clouds need to be better established than at present.

2. That dew-ponds cannot in the first instance be filled by rain (see Mr. Clutterbuck's prize essay). This statement, if it can stand inquiry, seems to be decisive against the sufficiency of rainfall.

On the other hand the restriction of dew-ponds to an area quickly and directly reached by south-west winds blowing from the sea, supports, it would seem, the view that what we call dew-ponds are really rain-ponds. Moisture-laden winds favour cloud-formation and rain, while we have no reason to suppose that they favour dew-formation, but rather the contrary.

Mr. Clement Reid, F.R.S., of the Geological Survey, sums up his wide experience of dew-ponds in these words :—

'The conditions that are required for a permanent dew-pond do not seem generally to be understood, failure or success appearing to be the result of chance rather than of any clear comprehension of the principle on which the dew-pond acts. On comparing, at the end of a long drought, the dried-up ponds with those that still contain water, we find that, other things being equal, the best dew-pond has the following characteristics :

'It is sheltered on the south-west side by an overhanging tree, often only a stunted ivy-covered thorn or oak, or by a bush of holly. Or else the hollow is sufficiently deep for the south bank to cut off much of the sun. The depth or shallowness of the water does not appear to make so great a difference as would be expected.

'The open downs, even in the middle of summer, receive much heavier dews than would be expected, or than are met with on the lowlands.

Thick sea-mists often cling to their tops for several hours after sunrise, while the plains below are already dry and sunny. It is only by noticing the large amount of moisture intercepted and dripping from the overhanging boughs as the sea-mist drifts slowly past that one can realise how prolific a source this must be. The amount condensed in this way might be tested by a rain-gauge of wide aperture.

'When one of these ponds is examined in the middle of a hot summer day it would appear that the few inches of water in it could only last a week. But in early morning or towards evening, or whenever a sea-mist drifts in, there is a continuous drip from the smooth leaves of the overhanging tree. There appears also to be a considerable amount of condensation on the surface of the water itself, though roads adjoining may be quite dry and dusty. In fact, whenever dew is on the grass, the dew-pond is receiving moisture; and this moisture, owing to the shade of the overhanging tree, is partly preserved throughout the day; so that sheep or cattle may drink daily from a small shallow pond which receives no rain, and yet the pond be not exhausted unless the nights are exceptionally dry.'

We now want observations by the thermometer. We should be glad to know the temperature of the water of the pond at various depths, as taken hourly through a summer night; the temperature of the surface of the ground (free from grass) a few feet away from the pond; the temperature of the air at various small heights above the hill-top, as well as in a neighbouring valley; and also the relative humidity of the air as determined by wet and dry bulbs. If a small party would make such observations during a few clear still nights in hot summer weather, some blanks in our knowledge would be filled up at once. We should be glad to know how the level of a dew-pond varies during a spell of sultry weather. Observations on the clouds and mists of the summits of the downs are also much to be desired. Day observations would have their use too, and should not be omitted.

Is it too much to ask that residents in the south-eastern counties will investigate these matters for us? A party of a dozen meteorologists who would choose a time of settled hot weather, and give a week to the inquiry, would throw much light upon a question of considerable scientific and practical importance.

While so many data are wanting, it would be unwise to express a confident opinion as to the relative importance of rain and dew in the supply of water to the ponds of the chalk downs. No scientific man will willingly decide any question on indirect evidence if direct evidence can be got.

In making inquiries about dew-ponds I have been helped by many friends and correspondents, among others by Mr. W. Whitaker, F.R.S., Mr. Clement Reid, F.R.S., Mr. John Hopkinson, Mr. T. W Shore, Mr. F. J. Bennett, Mr. John Brigg, M.P., Professor G. S. Brady, F R.S., and the Rev. Henry Green.

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The Chairman remarked that they would all unite in thanking Professor Miall for bringing before them the subject of dew-ponds in so complete a form. He should like to have a little further information as to the habit of sprinkling with lime with the object of keeping out earthworms. He wished also to know on what grounds Professor Miall said that evaporation from the surface of dew-ponds was slight. His own impression was that evaporation would be somewhat rapid. Professor Miall had spoken of the limited area within which dew-ponds existed. It was singular that this limited area was one of low rainfall. Dew-ponds were numerous in Berkshire, where they were made in the way described by Professor Miall. While the Hertfordshire chalk was largely covered by clay with flints, the Berkshire chalk was not.

Mr. Clement Reid said that the question of the water supply in dew-ponds was, like many other questions of water supply, much mixed up with curious ancient superstitious observances analogous to the use of the divining rod. He did not think that dew-ponds were formed in anything like the scientific manner pretended by their makers. He had been working during the last few years in a country where dew-ponds were particularly abundant, and there had been several successive years of severe drought. Nearly all the more recently made dew-ponds were dried up, but a number of the older ones had not dried up. He did not think that the older ponds were better made than the newer ones, but that a process leading to the survival of the fittest was always going on. When a dew-pond dried up a new one became necessary. The farmers were constantly making new ones, and sometimes, by accident, they got a satisfactory site. It was an unfortunate thing that they were almost entirely without meteorological observations on the high ground, where dew-ponds abounded, our rainfall stations being almost invariably at a low level. As to the question of dew or mist he did not feel qualified to speak. He wondered whether it was possible that the film of scum constantly seen on the surface of dew-ponds had any influence in protecting the water from evaporation. Dew-ponds, being entirely isolated from running water, were very important from a biological point of view. They could watch the population of a pond becoming more numerous and varied, and note how the higher animals and plants took the place of the lower which first appeared. Dew-ponds and other isolated ponds would give much valuable information as to the rate of dispersal of the aquatic fauna and

flora of a district, and their observation with this object was a matter which might well be recommended to all local scientific Societies.

Mr. Vaughan Cornish said that in Berkshire the dew-ponds were frequently in open situations and not under trees. He would bring the matter before the notice of the Dorsetshire Field Club, and he hoped they might be able to make some systematic observations on dew-ponds.

Mr. John Hopkinson noticed that Professor Miall held that the margin of the pond had very little effect in increasing the amount of rain collected, but he believed that, as a rule, the area of the margin was at least equal to that of the surface of the pond. There was thus twice the area for rainfall that would be given if the water-covered surface alone were reckoned. It was difficult to form an idea as to how water was contributed to these ponds by dew, as dew would require a surface cooler than the air on which to condense, whilst the water in the pond would usually cool more slowly than the air above it. The water being also warmer than the surface of the ground surrounding it, dew would not so readily condense on it. He believed that observations had been made, but he was not aware that any one had actually seen the dew accumulating on the side of a pond and trickling down into it. The margin had certainly very little, if any, effect as regards the amount of dew received. A distinction must be drawn between dew and mist: the latter would probably increase the amount of water in a pond. As to the level of these ponds, he believed that it varied considerably from time to time. Where there were trees overhanging the pond there would be a considerable deposition of dew, but he thought that the majority of these ponds were not surrounded by trees. As to evaporation from the ponds, mist was to be seen at times rising from their surface. He believed that the average rainfall where dew-ponds were situated was between twenty-five and thirty inches per annum. But there were scarcely any rain-gauges on the high ground where dew-ponds existed, and there was probably more rain on the hills than in the valleys. He did not know of any dew-ponds in Hertfordshire, though there was a considerable area around Royston and Hitchin where there was bare chalk. He thought the subject extremely interesting, and one which might be profitably studied by the local Societies. Among other results their investigations might some day enable farmers to fix upon the best possible sites for their dew-ponds, and so prevent the waste of a considerable amount of money.

Mr. Clement Reid remarked that the ponds which had stood the severe drought had generally trees on their margin.

Mr. J. Brown said that in order to form an accurate estimate of what was going on it would be necessary to consider the amount of water consumed by the animals drinking at the pond. There were no dew-ponds in Ireland.

The Chairman remarked that dew-ponds were only made in a country like that of the higher chalk districts, where the rocks were absolutely dry.

Mr. W. Gray said that there was a great deal of superstition about water, and some of the accounts of dew-ponds which never failed, &c., probably owed much to that source. There were wells in Ireland the water of which it was said would not boil, and the people never used it for cooking, because they thought that it would be useless for that purpose. This notion evidently arose from the fact that the water from a deep-seated source is of the same temperature in summer and winter, and

the inference of some people was that it would be of no use to attempt to change the temperature artificially.

Mr. W. M. Watts said that with regard to the mixture of lime with clay in the sides of a dew-pond, he did not think that was necessary to make them impervious; but lime was frequently mixed with sandy material to prevent it from slipping in the slope of a reservoir embankment. With regard to the amount of dew, that could hardly exceed one inch and a half per annum.

Mr. James Barrowman was not aware that there were any dew-ponds in Scotland. One point to be considered was whether the superficial area of the pond had anything to do with its success.

Mr. Hopkinson thought that it was of considerable importance in the construction of these ponds that in the summer the receiving area was usually more than double the evaporating area.

Mr. G. P. Hughes said that dew-ponds were unknown in his district. It occurred to him that they might prove useful in the future both in Australia and in South Africa—dry countries where the dews were very heavy.

The Rev. E. P. Knubley remarked that Wiltshire was a country of dew-ponds. He suggested that all the Delegates should be supplied with a list of questions, which they might attempt to answer by the date of the next meeting.

Professor Louis remarked that the exact composition of the water in these dew-ponds was one of the essential points to be examined.

Professor Potter said that in Warwickshire there were many ponds which it was almost impossible to suppose could be fed by surface drainage. In Suffolk there were a great number of small ponds which formed the water-supply of villages, and were covered over and not supplied by rain. In the south of Portugal there was a well-defined wet season of short duration and a prolonged summer, in which no rain fell at all. In that country there were many rock pools, and from the scarcity of the rainfall and the excessive heat it was impossible to suppose that these pools had been fed entirely by the rain.

Professor Miall replied, and expressed the hope that the Corresponding Societies would take up the subject and furnish additional information on dew-ponds.

The Chairman requested the Delegates to bring the subject before their Societies. Mr. Vaughan Cornish remarked that he would see what could be done in Hampshire and Berkshire to induce people to take the matter up. The Rev. E. P. Knubley added that he would try to interest some residents in Sussex.

Section C.

Mr. Monckton, representing Section C, drew attention to the labours of two Committees who wished to obtain the co-operation of the Corresponding Societies in their work, the Geological Photographs Committee and the Erratic Blocks Committee. As regards geological photographs, the county of Yorkshire and the scientific Societies of Yorkshire were pre-eminently first in the work up to the present time. The number of geological photographs in the British Association's collection was 2,655, the number received during the past year being 309. In this list he did not include a certain number of duplicates and lantern slides. It was so obvious that the taking of geological photographs was a work which could be most usefully done by members of the Societies that he need say nothing more on that head. Then the Committee for the Investigation of

the Erratic Blocks of the British Isles wished for the active co-operation of the members of the Corresponding Societies. Individual workers could greatly aid this investigation, but the most effective assistance would be given by the organisation of local Boulder Committees. He would therefore suggest that the Delegates should impress their respective Societies with the importance of organising local Boulder Committees, and of communicating the results attained to the Erratic Blocks Committee. It might be useful to add that the Secretary of the Geological Photographs Committee is Professor W. W. Watts, and the Secretary of the Erratic Blocks Committee Professor P. F. Kendall.

Section D.

The Rev. E. P. Knubley said that Section D was anxious to encourage the Corresponding Societies to go on observing birds, and especially the migration of birds. A new light had been thrown on the migration of birds by the observations of lighthouse and lightship keepers. Until recently it was thought that all birds had the same lines of flight, but now it was known that there were several. It was now known that the common thrush went backwards and forwards from our islands during about ten months of the year. It was found that the wagtail came regularly along the western coast, but was unknown on the east. It was desirable that they should learn how long the commonest English birds sat upon their eggs before hatching them. No one at present could answer that question. Then the subject of the food supply of birds was one which might well be studied. The life histories of insects was also a most interesting subject to work at.

Section E.

Mr. Sowerbutts said that he had some suggestions to make, though he could not precisely say that he made them on behalf of Section E. He thought that the Corresponding Societies should be placed permanently on the list so long as they conformed to the rules of the Association, and not be elected for a year only as at present. Secondly, the Delegate should be held responsible for the carrying out of anything required by the Association, and should be the correspondent with the Secretary of the Corresponding Societies Committee. It should also be his duty to report to the Society he represented on the subjects in which the British Association desired the co-operation of the Corresponding Societies. Before the end of the year he should forward to the Corresponding Societies Committee a copy of his report. And he should forward to the Secretary of the Corresponding Societies Committee before March in each year the name of any subject that his Society might wish should be considered by the Corresponding Societies Committee. He also proposed that a Delegate about to resign his post might introduce a new Delegate on sending his name to the Secretary of the Corresponding Societies Committee, the new Delegate not having the power of voting, and not becoming a member of the General Committee. Other questions also needed consideration. How long, for example, should a Corresponding Society remain on the list which did nothing asked for by the British Association? He thought that any Society which did not send a Delegate year after year should cease to be connected with the Association. And he would strongly urge also the enforcement of the Delegate's duty of reporting to his own Society and sending a copy of the report to the Secretary of the Corresponding Societies Committee.

The Chairman remarked that he was afraid they would be told that by regulations of this kind they were interfering with the internal management of the Societies.

Mr. Sowerbutts said that had always been a difficulty, but if the difficulty were not overcome the work of the Corresponding Societies Committee could hardly be carried to a profitable issue.

SECTION H.

Mr. E. Sidney Hartland, representing Section H, brought before the notice of the Conference the work of the Anthropological Photographs Committee, whose object was to collect photographs of objects of anthropological interest. At present the collection was to be placed in the rooms of the Anthropological Institute. The Committee thought that there must be in all parts of the country a considerable number of photographs of this kind of interest to students, but not at present available. They wanted photographs of prehistoric stone monuments, stone implements, primitive pottery, and of objects connected with local superstitions, &c. Objects of this kind were frequently to be met with in local museums. Sometimes they belonged to the locality, sometimes not. But at present their existence there was known only to the local men, and the Committee wished to make them available for all students of anthropology. The Secretary of the Committee was Mr. J. L. Myres.

The Rev. J. O. Bevan said that though the hour was late he wished to bring forward a proposition. It was 'that the Committees of the Corresponding Societies be invited to lay before their members the necessity of carrying on a systematic survey of their counties in respect to ethnography and ethnology, botany, meteorology, ornithology, archæology, folklore, &c.' This kind of work was being done in part at various places, but at present little was known of it by any central body, and thence probably there was some confusion and overlapping. The Society of Antiquaries were prepared to assist any local Society willing to take up the archæological survey of a county. The Committee of the British Association which was concerned with the ethnography and ethnology of the country was dissolved at the Dover meeting. He hoped that the Committees of the various local Societies would appoint members according to their several aptitudes to take up specific work, and that the Corresponding Societies Committee should be in a position to know what was being done, so as to regulate and co-ordinate the work and give it direction. He wished that some record might be kept of the resolution by placing it on the minutes.

The Chairman said that the only difficulty of putting the resolution was that the meeting was then so small that it would be hardly fair to take a vote. He suggested that the resolution should be referred to the Committee to deal with.

It was resolved that all the matters touched upon by Mr. Sowerbutts and Mr. Bevan should be referred to the Committee.

Mr. Hembry suggested that at future meetings matters connected with the different Sections should be taken before the reading of a paper on any special subject.

The Chairman said that this question might also be referred to the Committee.

The Corresponding Societies of the British Association for 1900–1901.

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204 George Street, Glasgow. R. Barnett Johnstone and R. McLean	192	None	2s. 6d.	Annals, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	Rev. W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	252	None	1l. 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. William Gray and Dr. W. D. Donnan	330	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	Rev. G. Gunn, M.A., Stichill, Kelso, N.B.	400	10s. 6d.	7s. 6d.	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Birm. & Mid. Inst. Sci. Soc.	H. C. Adams, Birmingham and Midland Institute, Paradise Street, Birmingham	141	None	1l. 6s.	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Norwich Union Chambers, Congreve Street, Birmingham. W. P. Marshall and P. L. Gray	183	None	1l. 1s.	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	Brighton N. H. Phil. Soc.	Museum, Church Street, Brighton. E. A. Pankhurst.	185	10s.	10s.	Report, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	S. H. Reynolds, M.A., University College, Bristol	152	5s.	10s.	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5 Chapel Street, Peterhead	180	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	B. L. Oswell, 30 High Street, Burton-on-Trent	220	None	5s.	Annual Report. Transactions occasionally.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C.	H. E. Forrest, 37 Castle Street, Shrewsbury.	190	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98 St. Mary Street, Cardiff	450	None	10s. 6d.	Transactions, annually.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. P. Miln and W. F. J. Shepheard	868	None	5s.	Report and Proceedings, annually.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. G. Alfred Lewis, Albert Street, Derby	360	1l. 1s. None	Members 31s. 6d.; Associates and Students 20s.	Transactions of Institution of Mining Engineers, monthly.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	200	10s. 6d.	Minimum, 10s. 6d.	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	The Museum, Public Buildings, Penzance. John B. Cornish	95	None	1l. 1s.	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. F. J. Townend	230	None	10s.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	Nelson M. Richardson, Montevideo, Chickerel, Weymouth	350	None	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	Dublin N. F. C.	N. H. Alcock, M.D., and C. J. Patten, M.D., Royal Irish Academy, Dublin	180	5s.	5s.	'Irish Naturalist,' monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. J. Maxwell Ross, St. Ruth's, Dumfries	205	2s. 6d.	5s.	Transactions and Journal of Proceedings, annually.
Eastbourne Natural History Society, 1869	Eastbourne N. H. Soc.	Dr. H. Habgood, Stafford House, Upperton Road, Eastbourne	112	2s. 6d.	7s. 6d.	Transactions, annually.
East Kent Scientific and Natural	E. Kent S. N. H. Soc.	H. Mead-Briggs, 8 High Street,	67	None	10s.	'South-Eastern Naturalist,'
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Annual Report

						occasionally.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Barclay Murdoch, Capelrig, Newton-Mearns, Glasgow	210	None	10*s.*	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	J. J. Robertson, 207 Bath Street, Glasgow	314 Memb. 18 Assoc.	None	Members 7*s.* 6*d.* Associates 5*s.*	Transactions and Proceedings, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	Peter Bennett, 207 Bath Street, Glasgow	675	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Halifax Scientific Society and Geological Field Club, 1874	Halifax S. S. G. F. C.	Literary and Philosophical Society's Rooms. F. Barker	108	None	2*s.* 6*d.*	'Halifax Naturalist,' every two months.
Hampshire Field Club and Archæological Society, 1885	Hants F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7*s.* 6*d.*	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	W. R. Carter, B.A., Amesbury, Watford	210	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	88	10*s.*	10*s.*	Proceedings, every two or three years.
Hull Geological Society, 1887	Hull Geol. Soc.	W. S. Parrish, 1 Waltham Street, Hull	71	None	5*s.*	Transactions, annually.
Hull Scientific and Field Naturalists' Club, 1886	Hull Sci. F. N. C.	T. Sheppard, F.G.S., 432 Holderness Road, Hull	170	None	4*s.* and 2*s.*	Transactions, annually.
Institution of Mining Engineers	Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	2,500	None	None	Transactions, monthly.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	E. G. Critchley, 29 High Street, Inverness	180	None	5*s.*	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	J. Pim, W. Lawson, and C. H. Oldham, 35 Molesworth Street, Dublin	100	None	1*l.*	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Philosophical Hall, Leeds. David Forsyth, M.A., D.Sc.	70	None	5*s.*	Transactions, occasionally.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	H. B. Wilson, Westfield, Armley, Leeds	150	None	6*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum. Herbert Ellis	330 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liv'pool E. Soc.	R. C. F. Annett, Royal Institution, Liverpool	502	None	Resident 1*l.* 1*s.* Non-Res. and Students 10*s.* 6*d.*	Transactions, annually.
Liverpool Geographical Society, 1891	Liv'pool Geog. Soc.	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Buildings, Chapel Street, Liverpool	750	None	Members 1*l.* 1*s.* Associates 10*s.* 6*d.*	Transactions and Report, annually.
Liverpool Geological Society, 1858	Liv'pool Geol. Soc.	Royal Institution. H. C. Beasley	55	None	21*s.*	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. J. Maxwell McMaster	214	None	1*l.* 1*s.*; Ladies 10*s.* 6*d.*	Proceedings, annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc.	Rev. F. J. R. Young, 95 Wold Road, Norton Malton, Yorks.	123	None	5*s.* and 2*s.* 6*d.*	Report, annually.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	158	2*s.* 6*d.*	Gentlemen 7*s.* 6*d.* Ladies and Non-Residents 5*s.*	Yn Lioar Manninagh, biennially.
Manchester Geographical Society, 1884	Manch. Geog. Soc.	Eli Sowerbutts, F.R.G.S., 16 St. Mary's Parsonage, Manchester	800	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Journal, quarterly; 'Geography,' monthly.
Manchester Geological Society, 1838	Manch. Geol. Soc.	5 John Dalton Street, Manchester. W. Saint and J. Tonge, jun.	240	None	1*l.*	Transactions, monthly.
Manchester Microscopical Society, 1880	Manch. Mic. Soc.	E. C. Stump, 16 Herbert Street, Moss Side, Manchester	210	5*s.*	6*s.*	Transactions and Report, annually.
Manchester Statistical Society, 1833	Manch. Stat. Soc.	63 Brown Street, Manchester. F. E. M. Beardsall and T. Gregory	210	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick	324	1*s.* 6*d.*	3*s.* and 5*s.*	Report, annually.
Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	Midland Inst. Eng.	T. W. H. Mitchell, Mining Offices, Regent Street, Barnsley	251	None	1*l.* 10*s.*	Transactions of Institution of Mining Engineers, monthly.

CORRESPONDING SOCIETIES, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, St. Helen's Square, Norwich	250	None	5*s.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,250	None	21*s.* and 42*s.*	Transactions of Institution of Mining Engineers, monthly.
North Staffordshire Field Club	N. Staff. F. C.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs; W. Wells Bladen, Stone, Staffs.	456	5*s.*	5*s.*	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc.	H. N. Dixon, M.A., 23 East Park Parade, Northampton	190	None	10*s.*	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of	Northumb. N. H. Soc.	Hancock Museum, Newcastle-on-Tyne. A. H. Dickinson and Prof. C. M. Potter	250	None	1*s.*	Transactions, annually.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Prof. J. W Carr, University College, Nottingham	150	2*s.* 6*d.*	5*s.*	Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	420	5*s.*	7*s.* 6*d.*	Report, annually; Meteorological Observations, occasionally.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc.	Museum, Public Buildings, Penzance. Dr. H. M. Montgomerie	71	None	10*s.* 6*d.*	Report, annually; Transactions, occasionally.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	410	2*s.* 6*d.*	5*s.* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, B.Sc., 105 Freehold Street, Rochdale	240	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Linden House, Rochester	150	None	5*s.*	'Rochester Naturalist,' quarterly.
Scotland, Mining Institute of, 1878	Mining Inst. Scot.	James Barrowman, Staneacre, Hamilton, N.B.	455	None	42*s.* and 25*s.*	Trans. Institution of Mining Engineers, monthly.
Somersetshire Archæological and Natural History Society, 1848	Som'setsh. A. N. H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble and Rev. F. W. Weaver	612	10*s.* 6*d.*	10*s.* 6*d.*	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc.	G. S. Corstorphine, South African Museum, Cape Town	132	None	2*l.*	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	S.-E. Union	George Abbott, M.R.C.S., 33 Upper Grosvenor Road, Tunbridge Wells	33 Societies	None	5*s.*	Transactions, annually.
South Staffordshire and East Worcestershire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng.	Alexander Smith, M.Inst.C.E., 3 Newhall Street, Birmingham	172	1*l.* 1*s.* and 10*s.* 6*d.*	31*s.* 6*d.* and 21*s.*	Transactions of Institution of Mining Engineers, monthly.
Toronto, Astronomical and Physical Society of, 1884	Toronto Astr. Phys. Soc.	Canadian Institute Building. Thos. Lindsay	100	None	2 dollars	Transactions, annually.
Tyneside Geographical Society 1887	Tyneside Geog. Soc.	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. Herbert Shaw, B.A.	1,200	None	10*s.* and 5*s.*	Journal, half-yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C.	Museum, Warwick. S. S. Stanley, 3 Regent Grove, Leamington	109	2*s.* 6*d.*	5*s.*	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	212	10*s.*	10*s.*	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, F.G.S., Hopton, Mirfield	168	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	W. Denison Roebuck, F.L.S., 259 Hyde Park Road, Leeds	432 and 2,418	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.

Index of the more important Papers, and especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending June 1, 1900.

⁂ This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

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TRANSACTIONS OF THE SECTIONS.

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SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

PRESIDENT OF THE SECTION—DR. JOSEPH LARMOR, F.R.S.

THURSDAY, SEPTEMBER 6.

The President delivered the following Address:—

IT is fitting that before entering upon the business of the Section we should pause to take note of the losses which our department of science has recently sustained. The fame of Bertrand, apart from his official position as Secretary of the French Academy of Sciences, was long ago universally established by his classical treatise on the Infinitesimal Calculus: it has been of late years sustained by the luminous exposition and searching criticism of his books on the Theory of Probability and Thermodynamics and Electricity. The debt which we owe to that other veteran, G. Wiedemann, both on account of his own researches, which take us back to the modern revival of experimental physics, and for his great and indispensable thesaurus of the science of electricity, cannot easily be overstated. By the death of Sophus Lie, following soon after his return to a chair in his native country Norway, we have lost one of the great constructive mathematicians of the century, who has in various directions fundamentally expanded the methods and conceptions of analysis by reverting to the fountain of direct geometrical intuition. In Italy the death of Beltrami has removed an investigator whose influence has been equally marked on the theories of transcendental geometry and on the progress of mathematical physics. In our own country we have lost in D. E. Hughes one of the great scientific inventors of the age; while we specially deplore the removal, in his early prime, of one who has recently been well known at these meetings, Thomas Preston, whose experimental investigations on the relations between magnetism and light, combined with his great powers of lucid exposition, marked out for him a brilliant future.

Perhaps the most important event of general scientific interest during the past year has been the definite undertaking of the great task of the international coordination of scientific literature; and it may be in some measure in the prolonged conferences that were necessitated by that object that the recently announced international federation of scientific academies has had its origin. In the important task of rendering accessible the stores of scientific knowledge, the British Association, and in particular this Section of it, has played the part of pioneer. Our annual volumes have long been classical, through the splendid reports of the progress of the different branches of knowledge that have been from time to time contributed to them by the foremost British men of science; and our work in this direction has received the compliment of successful imitation by the sister Associations on the Continent.

The usual conferences connected with our department of scientific activity have

been this year notably augmented by the very successful international congresses of mathematicians and of physicists which met a few weeks ago in Paris. The three volumes of reports on the progress of physical science during the last ten years, for which we are indebted to the initiative of the French Physical Society, will provide an admirable conspectus of the present trend of activity, and form a permanent record for the history of our subject.

Another very powerful auxiliary to progress is now being rapidly provided by the republication, in suitable form and within reasonable time, of the collected works of the masters of our science. We have quite recently received, in a large quarto volume, the mass of most important unpublished work that was left behind him by the late Professor J. C. Adams; the zealous care of Professor Sampson has worked up into order the more purely astronomical part of the volume; while the great undertaking, spread over many years, of the complete determination of the secular change of the magnetic condition of the earth, for which the practical preparations had been set on foot by Gauss himself, has been prepared for the press by Professor W. G. Adams. By the publication of the first volume of Lord Rayleigh's papers a series of memoirs which have formed a main stimulus to the progress of mathematical physics in this country during the past twenty years has become generally accessible. The completed series will form a landmark for the end of the century that may be compared with Young's 'Lectures on Natural Philosophy' for its beginning.

The recent reconstruction of the University of London, and the foundation of the University of Birmingham, will, it is to be hoped, give greater freedom to the work of our University Colleges. The system of examinations has formed an admirable stimulus to the effective acquisition of that general knowledge which is a necessary part of all education. So long as the examiner recognises that his function is a responsible and influential one, which is to be taken seriously from the point of view of moulding the teaching in places where external guidance is helpful, test by examination will remain a most valuable means of extending the area of higher education. Except for workers in rapidly progressive branches of technical science, a broad education seems better adapted to the purposes of life than special training over a narrow range; and it is difficult to see how a reasonably elastic examination test can be considered as a hardship. But the case is changed when preparation for a specialised scientific profession, or mastery of the lines of attack in an unsolved problem, is the object. The general education has then been presumably finished; in expanding departments of knowledge, variety rather than uniformity of training should be the aim, and the genius of a great teacher should be allowed free play without external trammels. It would appear that in this country we have recently been liable to unduly mix up two methods. We have been starting students on the special and lengthy, though very instructive, processes which are known as original research at an age when their time would be more profitably employed in rapidly acquiring a broad basis of knowledge. As a result, we have been extending the examination test from the general knowledge to which it is admirably suited into the specialised activity which is best left to the stimulus of personal interest. Informal contact with competent advisers, themselves imbued with the scientific spirit, who can point the way towards direct appreciation of the works of the masters of the science, is far more effective than detailed instruction at second hand, as regards growing subjects that have not yet taken on an authoritative form of exposition. Fortunately there seems to be now no lack of such teachers to meet the requirements of the technical colleges that are being established throughout the country.

The famous treatise which opened the modern era by treating magnetism and electricity on a scientific basis appeared just 300 years ago. The author, William Gilbert, M.D., of Colchester, passed from the Grammar School of his native town to St. John's College, Cambridge: soon after taking his first degree, in 1560, he became a Fellow of the College, and seems to have remained in residence, and taken part in its affairs, for about ten years. All through his subsequent career, both at Colchester and afterwards at London, where he attained the highest position in his profession, he was an exact and diligent explorer,

first of chemical and then of magnetic and electric phenomena. In the words of the historian Hallam, writing in 1839, 'in his Latin treatise on the Magnet he not only collected all the knowledge which others had possessed, but he became at once the father of experimental philosophy in this island;' and no demur would be raised if Hallam's restriction to this country were removed. Working nearly a century before the time when the astronomical discoveries of Newton had originated the idea of attraction at a distance, he established a complete formulation of the interaction of magnets by what we now call the exploration of their fields of force. His analysis of the facts of magnetic influence, and incidentally of the points in which it differs from electric influence, is virtually the one which Faraday re-introduced. A cardinal advance was achieved, at a time when the Copernican Astronomy had still largely to make its way, by assigning the behaviour of the compass and the dip needle to the fact that the earth itself is a great magnet, by whose field of influence they are controlled. His book passed through many editions on the Continent within forty years: it won the high praise of Galileo. Gilbert has been called 'the father of modern electricity by Priestley, and 'the Galileo of magnetism' by Poggendorff.

When the British Association last met at Bradford in 1873 the modern theory which largely reverts to Gilbert's way of formulation, and refers electric and magnetic phenomena to the activity of the æther instead of attractions at a distance, was of recent growth: it had received its classical exposition only two years before by the publication of Clerk Maxwell's treatise. The new doctrine was already widely received in England on its own independent merits. On the Continent it was engaging the strenuous attention of Helmholtz, whose series of memoirs, deeply probing the new ideas in their relation to the prevalent and fairly successful theories of direct action across space, had begun to appear in 1870. During many years the search for crucial experiments that would go beyond the results equally explained by both views met with small success; it was not until 1887 that Hertz, by the discovery of the æthereal radiation of long wave-length emitted from electric oscillators, verified the hypothesis of Faraday and Maxwell and initiated a new era in the practical development of physical science. The experimental field thus opened up was soon fully occupied both in this country and abroad; and the borderland between the sciences of optics and electricity is now being rapidly explored. The extension of experimental knowledge was simultaneous with increased attention to directness of explanation; the expositions of Heaviside and Hertz and other writers fixed attention, in a manner already briefly exemplified by Maxwell himself, on the inherent simplicity of the completed æthereal scheme, when once the theoretical scaffolding employed in its construction and dynamical consolidation is removed; while Poynting's beautiful corollary specifying the path of the transmission of energy through the æther has brought the theory into simple relations with the applications of electrodynamics.

Equally striking has been the great mastery obtained during the last twenty years over the practical manipulation of electric power. The installation of electric wires as the nerves connecting different regions of the earth had attained the rank of accomplished fact so long ago as 1857, when the first Atlantic cable was laid. It was largely the theoretical and practical difficulties, many of them unforeseen, encountered in carrying that great undertaking to a successful issue, that necessitated the elaboration by Lord Kelvin and his coadjutors of convenient methods and instruments for the exact measurement of electric quantities, and thus prepared the foundation for the more recent practical developments in other directions. On the other hand, the methods of theoretical explanation have been in turn improved and simplified through the new ways of considering the phenomena which have been evolved in the course of practical advances on a large scale, such as the improvement of dynamo armatures, the conception and utilisation of magnetic circuits, and the transmission of power by alternating currents. In our time the relations of civilised life have been already perhaps more profoundly altered than ever before, owing to the establishment of practically instantaneous electric communication between all parts of the world. The

employment of the same subtle agency is now rapidly superseding the artificial reciprocating engines and other contrivances for the manipulation of mechanical power that were introduced with the employment of steam. The possibilities of transmitting power to great distances at enormous tension, and therefore with very slight waste, along lines merely suspended in the air, are being practically realised; and the advantages thence derived are increased manifold by the almost automatic manner in which the electric power can be transformed into mechanical rotation at the very point where it is desired to apply it. The energy is transmitted at such lightning speed that at a given instant only an exceedingly minute portion of it is in actual transit. When the tension of the alternations is high, the amount of electricity that has to oscillate backwards and forwards on the guiding wires is proportionately diminished, and the frictional waste reduced. At the terminals the direct transmission from one armature of the motor to the other, across the intervening empty space, at once takes us beyond the province of the pushing and rubbing contacts that are unavoidable in mechanical transmission; while the perfect symmetry and reversibility of the arrangement by which power is delivered from a rotatory alternator at one end, guided by the wires to another place many miles away, where it is absorbed by another alternator with precise reversal of the initial stages, makes this process of distribution of energy resemble the automatic operations of nature rather than the imperfect material connections previously in use. We are here dealing primarily with the flawless continuous medium which is the transmitter of radiant energy across the celestial spaces; the part played by the coarsely constituted material conductor is only that of a more or less imperfect guide which directs the current of æthereal energy. The wonderful nature of this theoretically perfect, though of course practically only approximate, method of abolishing limitations of locality with regard to mechanical power is not diminished by the circumstance that its principle must have been in some manner present to the mind of the first person who fully realised the character of the reversibility of a Gramme armature.

In theoretical knowledge a new domain, to which the theory as expounded twenty years ago had little to say, has recently been acquired through the experimental scrutiny of the electric discharge in rarefied gaseous media. The very varied electric phenomena of vacuum tubes, whose electrolytic character was first practically established by Schuster, have been largely reduced to order through the employment of the high exhaustions introduced and first utilised by Crookes. Their study under these circumstances, in which the material molecules are so sparsely distributed as but rarely to interfere with each other, has conduced to enlarged knowledge and verification of the fundamental relations in which the individual molecules stand to all electric phenomena, culminating recently in the actual determination, by J. J. Thomson and others following in his track, of the masses and velocities of the particles that carry the electric discharge across the exhausted space. The recent investigations of the circumstances of the electric dissociation produced in the atmosphere and in other gases by ultra-violet light, the Röntgen radiation, and other agencies, constitute one of the most striking developments in experimental molecular physics since Graham determined the molecular relations of gaseous diffusion and transpiration more than half a century ago. This advance in experimental knowledge of molecular phenomena, assisted by the discovery of the precise and rational effect of magnetism on the spectrum, has brought into prominence a modification or rather development of Maxwell's exposition of electric theory, which was dictated primarily by the requirements of the abstract theory itself; the atoms or ions are now definitely introduced as the carriers of those electric charges which interact across the æther, and so produce the electric fields whose transformations were the main subject of the original theory.

We are thus inevitably led, in electric and æthereal theory, as in the chemistry and dynamics of the gaseous state which is the department of abstract physics next in order of simplicity, to the consideration of the individual molecules of matter. The theoretical problems which had come clearly into view a quarter of a century ago, under Maxwell's lead, whether in the exact dynamical relations

of æthereal transmission or in the more fortuitous domain of the statistics of interacting molecules, are those around which attention is still mainly concentrated; but as the result of the progress in each, they are now tending towards consolidation into one subject. I propose—leaving further review of the scientific aspect of the recent enormous development of the applications of physical science for hands more competent to deal with the practical side of that subject—to offer some remarks on the scope and validity of this molecular order of ideas, to which the trend of physical explanation and development is now setting in so pronounced a manner.

If it is necessary to offer an apology for detaining the attention of the Section on so abstract a topic, I can plead its intrinsic philosophical importance. The hesitation so long felt on the Continent in regard to discarding the highly developed theories which analysed all physical actions into direct attractions between the separate elements of the bodies concerned, in favour of a new method in which our ideas are carried into regions deeper than the phenomena, has now given place to eager discussion of the potentialities of the new standpoint. There has even appeared a disposition to consider that the Newtonian dynamical principles, which have formed the basis of physical explanation for nearly two centuries, must be replaced in these deeper subjects by a method of direct description of the mere course of phenomena, apart from any attempt to establish causal relations; the initiation of this method being traced, like that of the Newtonian dynamics itself, to this country. The question has arisen as to how far the new methods of æthereal physics are to be considered as an independent departure, how far they form the natural development of existing dynamical science. In England, whence the innovation came, it is the more conservative position that has all along been occupied. Maxwell was himself trained in the school of physics established in this country by Sir George Stokes and Lord Kelvin, in which the dominating idea has been that of the strictly dynamical foundation of all physical action. Although the pupil's imagination bridged over dynamical chasms, across which the master was not always able to follow, yet the most striking feature of Maxwell's scheme was still the dynamical framework into which it was built. The more advanced reformers have now thrown overboard the apparatus of potential functions which Maxwell found necessary for the dynamical consolidation or his theory, retaining only the final result as a verified descriptive basis for the phenomena. In this way all difficulties relating to dynamical development and indeed consistency are avoided, but the question remains as to how much is thereby lost. In practical electro-magnetics the transmission of power is now the most prominent phenomenon; if formal dynamics is put aside in the general theory, its guidance must here be replaced by some more empirical and tentative method of describing the course of the transmission and transformation of mechanical energy in the system.

The direct recognition in some form, either explicitly or tacitly, of the part played by the æther has become indispensable to the development and exposition of general physics ever since the discoveries of Hertz left no further room for doubt that this physical scheme of Maxwell was not merely a brilliant speculation, but constituted, in spite of outstanding gaps and difficulties, a real formulation of the underlying unity in physical dynamics. The domain of abstract physics is in fact roughly divisible into two regions. In one of them we are mainly concerned with interactions between one portion of matter and another portion occupying a different position in space; such interactions have very uniform and comparatively simple relations; and the reason is traceable to the simple and uniform constitution of the intervening medium in which they have their seat. The other province is that in which the distribution of the material molecules comes into account. Setting aside the ordinary dynamics of matter in bulk, which is founded on the uniformity of the properties of the bodies concerned and their experimental determination, we must assign to this region all phenomena which are concerned with the uncoordinated motions of the molecules, including the range of thermal and in part of radiant actions; the only possible basis for detailed theory is the statistical dynamics of the distribution of the molecules. The far more deep-seated and

mysterious processes which are involved in changes in the constitution of the individual molecules themselves are mainly outside the province of physics, which is competent to reason only about permanent material systems; they must be left to the sciences of chemistry and physiology. Yet the chemist proclaims that he can determine only the results of his reactions and the physical conditions under which they occur; the character of the bonds which hold atoms in their chemical combinations is at present unknown, although a large domain of very precise knowledge relating, in some diagrammatic manner, to the topography of the more complex molecules has been attained. The vast structure which chemical science has in this way raised on the narrow foundation of the atomic theory is perhaps the most wonderful existing illustration both of the rationality of natural processes and of the analytical powers of the human mind. In a word, the complication of the material world is referable to the vast range of structure and of states of aggregation in the material atoms; while the possibility of a science of physics is largely due to the simplicity of constitution of the universal medium through which the individual atoms interact on each other.

The reference of the uniformity in the interactions at a distance between material bodies to the part played by the æther is a step towards the elimination of extraneous and random hypotheses about laws of attraction between atoms. It also places that medium on a different basis from matter, in that its mode of activity is simple and regular, whereas intimate material interactions must be of illimitable complexity. This gives strong ground for the view that we should not be tempted towards explaining the simple group of relations which have been found to define the activity of the æther, by treating them as mechanical consequences of concealed structure in that medium; we should rather rest satisfied with having attained to their exact dynamical correlation, just as geometry explores or correlates, without explaining, the descriptive and metric properties of space. On the other hand, a view is upheld which considers the pressures and thrusts of the engineer, and the strains and stresses in the material structures by which he transmits them from one place to another, to be the archetype of the processes by which all mechanical effect is transmitted in nature. This doctrine implies an expectation that we may ultimately discover something analogous to structure in the celestial spaces, by means of which the transmission of physical effect will be brought into line with the transmission of mechanical effect by material framework.

At a time when the only definitely ascertained function of the æther was the undulatory propagation of radiant energy across space, Lord Kelvin pointed out that, by reason of the very great velocity of propagation, the density of the radiant energy in the medium at any place must be extremely small in comparison with the amount of energy that is transmitted in a second of time: this easily led him to the very striking conclusion that, on the hypothesis that the æther is like material elastic media, it is not necessary to assume its density to be more than 10^{-18} of that of water, or its optical rigidity to be more than ten 10^{-8} of that of steel or glass. Thus far the æther would be merely an impalpable material atmosphere for the transference of energy by radiation, at extremely small densities but with very great speed, while ordinary matter would be the seat of practically all this energy. But this way of explaining the absence of sensible influence of the æther on the phenomena of material dynamics lost much of its basis as soon as it was recognised that the same medium must be the receptacle of very high densities of energy in the electric fields around currents and magnets.[1] The other mode of explanation

[1] We can here only allude to Lord Kelvin's recent most interesting mechanical illustrations of a solid æther interacting with material molecules and with itself by attraction at a distance: unlike the generalised dynamical methods expounded in the text, which can leave the intimate structure of the material molecule outside the problem, a definite working constitution is there assigned to the molecular nucleus. It is pointed out in a continuation that is to appear in the *Phil. Mag.* for September, that a density of æther of the order of only 10^{-9}, which would not appreciably affect the inertia of matter, would involve rigidity comparable with that of steel, and thus permit transmission of magnetic forces by stress; this solid æther is however, as usual, taken to be freely permeable to the molecules of matter.

is to consider the æther to be of the very essence of all physical actions, and to correlate the absence of obvious mechanical evidence of its intervention with its regularity and universality.

On this plan of making the æther the essential factor in the transformation of energy as well as its transmission across space, the material atom must be some kind of permanent nucleus that retains around itself an æthereal field of physical influence, such as, for example, a field of strain. We can recognise the atom only through its interactions with other atoms that are so far away from it as to be practically independent systems; thus our direct knowledge of the atom will be confined to this field of force which belongs to it. Just as the exploration of the distant field of magnetic influence of a steel magnet, itself concealed from view, cannot tell us anything about the magnet except the amount and direction of its moment, so a practically complete knowledge of the field of physical influence of an atom might be expressible in terms of the numerical values of a limited number of physical moments associated with it, without any revelation as to its essential structure or constitution being involved. This will at any rate be the case for ultimate atoms if, as is most likely, the distances at which they are kept apart are large compared with the diameters of the atomic nuclei; it in fact forms our only chance for penetrating to definite dynamical views of molecular structure. So long as we cannot isolate a single molecule, but must deal observationally with an innumerable distribution of them, even this kind of knowledge will be largely confined to average values. But the last half-century has witnessed the successful application of a new instrument of research, which has removed in various directions the limitations that had previously been placed on the knowledge to which it was possible for human effort to look forward. The spectroscope has created a new astronomy by revealing the constitutions and the unseen internal motions of the stars. Its power lies in the fact that it does take hold of the internal relations of the individual molecule of matter, and provide a very definite and detailed, though far from complete, analysis of the vibratory motions that are going on in it; these vibrations being in their normal state characteristic of its dynamical constitution, and in their deviations from the normal giving indications of the velocity of its movement and the physical state of its environment. Maxwell long ago laid emphasis on the fact that a physical atomic theory is not competent even to contemplate the vast mass of potentialities and correlations of the past and the future, that biological theory has to consider as latent in a single organic germ containing at most only a few million molecules. On our present view we can accept his position that the properties of such a body cannot be those of a 'purely material system,' provided, however, we restrict this phrase to apply to physical properties as here defined. But an exhaustive discovery of the intimate nature of the atom is beyond the scope of physics; questions as to whether it must not necessarily involve in itself some image of the complexity of the organic structures of which it can form a correlated part must remain a subject of speculation outside the domain of that science. It might be held that this conception of discrete atoms and continuous æther really stands, like those of space and time, in intimate relation with our modes of mental apprehension, into which any consistent picture of the external world must of necessity be fitted. In any case it would involve abandonment of all the successful traditions of our subject if we ceased to hold that our analysis can be formulated in a consistent and complete manner, so far as it goes, without being necessarily an exhaustive account of phenomena that are beyond our range of experiment. Such phenomena may be more closely defined as those connected with the processes of intimate combination of the molecules: they include the activities of organic beings which all seem to depend on change of molecular structure.

If, then, we have so small a hold on the intimate nature of matter, it will appear all the more striking that physicists have been able precisely to divine the mode of operation of the intangible æther, and to some extent explore in it the fields of physical influence of the molecules. On consideration we recognise that this knowledge of fundamental physical interaction has been reached by a comparative process. The mechanism of the propagation of light could never have been studied

in the free æther of space alone. It was possible, however, to determine the way in which the characteristics of optical propagation are modified, but not wholly transformed, when it takes place in a transparent material body instead of empty space. The change in fact arises on account of the æther being entangled with the network of material molecules; but inasmuch as the length of a single wave of radiation covers thousands of these molecules the wave-motion still remains uniform and does not lose its general type. A wider variation of the experimental conditions has been provided for our examination in the case of those substances in which the phenomenon of double refraction pointed to a change of the æthereal properties which varied in different directions; and minute study of this modification has proved sufficient to guide to a consistent appreciation of the nature of this change, and therefore of the mode of æthereal propagation that is thus altered. In the same way, it was the study and development of the manner in which the laws of electric phenomena in material bodies had been unravelled by Ampère and Faraday, that guided Faraday himself and Maxwell—who were impressed with the view that the æther was at the bottom of it all— in their progress towards an application of similar laws to æther devoid of matter, such as would complete a scheme of continuous action by consistently interconnecting the material bodies and banishing all untraced interaction across empty space. Maxwell in fact chose to finally expound the theory by ascribing to the æther of free space a dielectric constant and a magnetic constant of the same types as had been found to express the properties of material media, thus extending the seat of the phenomena to all space on the plan of describing the activity of the æther in terms of the ordinary electric ideas. The converse mode of development, starting with the free æther under the directly dynamical form which has been usual in physical optics, and introducing the influence of the material atoms through the electric charges which are involved in their constitution,[1] was hardly employed by him; in part, perhaps, because, owing to the necessity of correlating his theory with existing electric knowledge and the mode of its expression, he seems never to have reached the stage of moulding it into a completely deductive form.

The dynamics of the æther, in fact the recognition of the existence of an æther, has thus, as a matter of history, been reached through study of the dynamical phenomena of matter. When the dynamics of a material system is worked up to its purest and most general form, it becomes a formulation of the relations between the succession of the configurations and states of motion of the system, the assistance of an independent idea of force not being usually required. We can, however, only attain to such a compact statement when the system is self-contained, when its motion is not being dissipated by agencies of frictional type, and when its connections can be directly specified by purely geometrical relations between the coordinates, thus excluding such mechanisms as rolling contacts. The course of the system is then in all cases determined by some form or other of a single fundamental property, that any alteration in any small portion of its actual course must produce an increase in the total 'Action' of the motion. It is to be observed that in employing this law of minimum as regards the Action expressed as an integral over the whole time of the motion, we no more introduce the future course as a determining influence on the present state of motion than we do in drawing a straight line from any point in any direction, although the length of the line is the minimum distance between its ends. In drawing the line piece by piece we have to make tentative excursions into the immediate future in order to adjust each element into straightness with the previous element; so in tracing the next stage of the motion of a material system we have similarly to secure that it is not given any such directions as would unduly increase the Action. But whatever views may be held as to the ultimate significance of this principle of Action, its importance,

[1] In 1870 Maxwell, while admiring the breadth of the theory of Weber, which is virtually based on atomic charges combined with action at a distance, still regarded it as irreconcilable with his own theory, and left to the future the question as to why 'theories apparently so fundamentally opposed should have so large a field of truth common to both.'—'Scientific Papers,' ii. p. 228.

not only for mathematical analysis, but as a guide to physical exploration, remains fundamental. When the principles of the dynamics of material systems are refined down to their ultimate common basis, this principle of minimum is what remains. Hertz preferred to express its contents in the form of a principle of straightness of course or path. It will be recognised, on the lines already indicated, that this is another mode of statement of the same fundamental idea; and the general equivalence is worked out by Hertz on the basis of Hamilton's development of the principles of dynamics. The latter mode of statement may be adaptable so as to avoid the limitations which restrict the connections of the system, at the expense, however, of introducing new variables; if, indeed, it does not introduce gratuitous complexity for purposes of physics to attempt to do this. However these questions may stand, this principle of straightness or directness of path forms, wherever it applies, the most general and comprehensive formulation of purely dynamical action: it involves in itself the complete course of events. In so far as we are given the algebraic formula for the time-integral which constitutes the Action, expressed in terms of any suitable coordinates, we know implicitly the whole dynamical constitution and history of the system to which it applies. Two systems in which the Action is expressed by the same formula are mathematically identical, are physically precisely correlated, so that they have all dynamical properties in common. When the structure of a dynamical system is largely concealed from view, the safest and most direct way towards an exploration of its essential relations and connections, and in fact towards answering the prior question as to whether it is a purely dynamical system at all, is through this order of ideas. The ultimate test that a system is a dynamical one is not that we shall be able to trace mechanical stresses throughout it, but that its relations can be in some way or other consolidated into accordance with this principle of minimum Action. This definition of a dynamical system in terms of the simple principle of directness of path may conceivably be subject to objection as too wide; it is certainly not too narrow; and it is the conception which has naturally been evolved from two centuries of study of the dynamics of material bodies. Its very great generality may lead to the objection that we might completely formulate the future course of a system in its terms, without having obtained a working familiarity with its details, of the kind to which we have become accustomed in the analysis of simple material systems; but our choice is at present between this kind of formulation, which is a real and essential one, and an empirical description of the course of phenomena combined with explanations relating to more or less isolated groups. The list of great names, including Kelvin, Maxwell, Helmholtz, that have been associated with the employment of the principle for the elucidation of the relations of deep-seated dynamical phenomena, is a strong guarantee that we shall do well by making the most of this clue.

Are we then justified in treating the material molecule, so far as revealed by the spectroscope, as a dynamical system coming under this specification? Its intrinsic energy is certainly permanent and not subject to dissipation; otherwise the molecule would gradually fade out of existence. The extreme precision and regularity of detail in the spectrum shows that the vibrations which produce it are exactly synchronous, whatever be their amplitude, and in so far resemble the vibrations of small amplitude in material systems. As all indications point to the molecule being a system in a state of intrinsic motion, like a vortex ring, or a stellar system in astronomy, we must consider these radiating vibrations to take place around a steady state of motion which does not itself radiate, not around a state of rest. Now not the least of the advantages possessed by the Action principle, as a foundation for theoretical physics, is the fact that its statement can be adapted to systems involving in their constitution permanent steady motions of this kind, in such a way that only the variable motions superposed on them come into consideration. The possibilities as regards physical correlation of thus introducing permanent motional states as well as permanent structure into the constitution of our dynamical systems have long been emphasised by Lord Kelvin;[1]

[1] For a classical exposition see his *Brit. Assoc.* Address of 1884 on 'Steps towards Kinetic Theory of Matter,' reprinted in 'Popular Lectures and Addresses,' vol. i.

the effective adaptation of abstract dynamics to such systems was made independently by Kelvin and Routh about 1877; the more recent exposition of the theory by Helmholtz has directed general attention to what is undoubtedly the most significant extension of dynamical analysis which has taken place since the time of Lagrange.

Returning to the molecules, it is now verified that the Action principle forms a valid foundation throughout electrodynamics and optics; the introduction of the æther into the system has not affected its application. It is therefore a reasonable hypothesis that the principle forms an allowable foundation for the dynamical analysis of the radiant vibrations in the system formed by a single molecule and surrounding æther; and the knowledge which is now accumulating, both of the orderly grouping of the lines of the spectrum and of the modifications impressed on these lines by a magnetic field or by the density of the matter immediately surrounding the vibrating molecule, can hardly fail to be fruitful for the dynamical analysis of its constitution. But let it be repeated that this analysis would be complete when a formula for the dynamical energy of the molecule is obtained, and would go no deeper. Starting from our definitely limited definition of the nature of a dynamical system, the problem is merely to correlate the observed relations of the periods of vibration in a molecule, when it has come into a steady state as regards constitution and is not under the influence of intimate encounter with other molecules.

It may be recalled incidentally that the generalised Maxwell-Boltzmann principle of the equable distribution of the acquired store of kinetic energy of the molecule, among its various possible independent types of motion, is based directly on the validity of the Action principle for its dynamics. In the demonstrations usually offered the molecule is considered to have no permanent or constitutive energy of internal motion. It can, however, be shown, by use of the generalisation aforesaid of the Action principle, that no discrepancy will arise on that account. Such intrinsic kinetic energy virtually adds on to the potential energy of the system; and the remaining or acquired part of the kinetic energy of the molecule may be made the subject of the same train of reasoning as before.

Let us now return to the general question whether our definition of a dynamical system may not be too wide. As a case in point, the single principle of Action has been shown to provide a definite and sufficient basis for electrodynamics; yet when, for example, one armature of an electric motor pulls the other after it without material contact, and so transmits mechanical power, no connection between them is indicated by the principle such as could by virtue of internal stress transmit the pull. The essential feature of the transmission of a pull by stress across a medium is that each element of volume of the medium acts by itself, independently of the other elements. The stress excited in any element depends on the strain or other displacement occurring in that element alone; and the mechanical effect that is transmitted is considered as an extraneous force applied at one place in the medium, and passed on from element to element through these internal pressures and tractions until it reaches another place. We have, however, to consider two atomic electric charges as being themselves some kind of strain configurations in the æther; each of them already involves an atmosphere of strain in the surrounding æther which is part of its essence, and cannot be considered apart from it; each of them essentially pervades the entire space, though on account of its invariable character we consider it as a unit. Thus we appear to be debarred from imagining the æther to act as an elastic connection which is merely the agent of transmission of a pull from the one nucleus to the other, because there are already stresses belonging to and constituting an intrinsic part of the terminal electrons, which are distributed all along the medium. Our Action criterion of a dynamical system, in fact, allows us to reason about an electron as a single thing, notwithstanding that its field of energy is spread over the whole medium; it is only in material solid bodies, and in problems in which the actual sphere of physical action of the molecule is small compared with the smallest element of volume that our analysis considers, that the familiar idea of transmission of force by simple stress can apply. Whatever view may

ultimately commend itself, this question is one that urgently demands decision. A very large amount of effort has been expended by Maxwell, Helmholtz, Heaviside, Hertz, and other authorities in the attempt to express the mechanical phenomena of electrical action in terms of a transmitting stress. The analytical results up to a certain point have been promising, most strikingly so at the beginning, when Maxwell established the mathematical validity of the way in which Faraday was accustomed to represent to himself the mechanical interactions across space, in terms of a tension along the lines of force equilibrated by an equal pressure preventing their expansion sideways. According to the views here developed, that ideal is an impossible one; if this could be established to general satisfaction the field of theoretical discussion would be much simplified.

This view that the atom of matter is, so far as regards physical actions, of the nature of a structure in the æther involving an atmosphere of æthereal strain all around it, not a small body which exerts direct actions at a distance on other atoms according to extraneous laws of force, was practically foreign to the eighteenth century, when mathematical physics was modelled on the Newtonian astronomy and dominated by its splendid success. The scheme of material dynamics, as finally compactly systematised by Lagrange, had therefore no direct relation to such a view, although it has proved wide enough to include it. The remark has often been made that it is probably owing to Faraday's mathematical instinct, combined with his want of acquaintance with the existing analysis, that the modern theory of the æther obtained a start from the electric side. Through his teaching and the weight of his authority, the notion of two electric currents exerting their mutual forces by means of an intervening medium, instead of by direct attraction across space, was at an early period firmly grasped in this country. In 1845 Lord Kelvin was already mathematically formulating, with most suggestive success, continuous elastic connections, by whose strain the fields of activity of electric currents or of electric distributions could be illustrated; while the exposition of Maxwell's interconnected scheme, in the earlier form in which it relied on concrete models of the electric action, goes back almost to 1860. Corresponding to the two physical ideals of isolated atoms exerting attraction at a distance, and atoms operating by atmospheres of æthereal strain, there are, as already indicated, two different developments of dynamical theory. The original Newtonian equations of motion determined the course of a system by expressing the rates at which the velocity of each of its small parts or elements is changing. This method is still fully applicable to those problems of gravitational astronomy in which dynamical explanation was first successful on a grand scale, the planets being treated as point-masses, each subject to the gravitational attraction of the other bodies. But the more recent development of the dynamics of complex systems depends on the fact that analysis has been able to reduce within manageable limits the number of varying quantities whose course is to be explicitly traced, through taking advantage of those internal relations of the parts of the system that are invariable, either geometrically or dynamically. Thus, to take the simplest case, the dynamics of a solid body can be confined to a discussion of its three components of translation and its three components of rotation, instead of the motion of each element of its mass. With the number of independent coordinates thus diminished, when the initial state of the motion is specified the subsequent course of the complete system can be traced; but the course of the changes in any part of it can only be treated in relation to the motion of the system as a whole. It is just this mode of treatment of a system as a whole that is the main characteristic of modern physical analysis. The way in which Maxwell analysed the interactions of a system of linear electric currents, previously treated as if each were made up of small independent pieces or elements, and accumulated the evidence that they formed a single dynamical system, is a trenchant example. The interactions of vortices in fluid form a very similar problem, which is of special note in that the constitution of the system is there completely known in advance, so that the two modes of dynamical exposition can be compared. In this case the older method forms independent equations for the motion of each material element of the fluid, and so requires the introduction of the stress—here the fluid pressure—by which

dynamical effect is passed on to it from the surrounding elements: it corresponds to a method of contact action. But Helmholtz opened up new ground in the abstract dynamics of continuous media when he recognised (after Stokes) that, if the distribution of the velocity of spin at those places in the fluid where the motion is vortical be assigned, the motion in every part of the fluid is therein kinematically involved. This, combined with the theorem of Lagrange and Cauchy, that the spin is always confined to the same portions of the fluid, formed a starting-point for his theory of vortices, which showed how the subsequent course of the motion can be ascertained without consideration of pressure or other stress.

The recognition of the permanent state of motion constituting a vortex ring as a determining agent as regards the future course of the system was in fact justly considered by Helmholtz as one of his greatest achievements. The principle had entirely eluded the attention of Lagrange and Cauchy and Stokes, who were the pioneers in this fundamental branch of dynamics, and had virtually prepared all the necessary analytical material for Helmholtz's use. The main import of this advance lay, not in the assistance which it afforded to the development of the complete solution of special problems in fluid motion, but in the fact that it constituted the discovery of the types of permanent motion of the system, which could combine and interact with each other without losing their individuality,[1] though each of them pervaded the whole field. This rendered possible an entirely new mode of treatment; and mathematicians who were accustomed, as in astronomy, to aim directly at the determination of all the details of the special case of motion, were occasionally slow to apprehend the advantages of a procedure which stopped at formulating a description of the nature of the interaction between various typical groups of motions into which the whole disturbance could be resolved.

The new train of ideas introduced into physics by Faraday was thus consolidated and emphasised by Helmholtz's investigations of 1858 in the special domain of hydrodynamics. In illustration let us consider the fluid medium to be pervaded by permanent vortices circulating round solid rings as cores: the older method of analysis would form equations of motion for each element of the fluid, involving the fluid pressure, and by their integration would determine the distribution of pressure on each solid ring, and thence the way it moves. This method is hardly feasible even in the simplest cases. The natural plan is to make use of existing simplifications by regarding each vortex as a permanent reality, and directly attacking the problem of its interactions with the other vortices. The energy of the fluid arising from the vortex motion can be expressed in terms of the positions and strengths of the vortices alone; and then the principle of Action, in the generalised form which includes steady motional configurations as well as constant material configurations, affords a method of deducing the motions of the cores and the interactions between them. If the cores are thin they in fact interact mechanically, as Lord Kelvin and Kirchhoff proved, in the same manner as linear electric currents would do; though the impulse thence derived towards a direct hydro-kinetic explanation of electro-magnetics was damped by the fact that repulsion and attraction have to be interchanged in the analogy. The conception of vortices, once it has been arrived at, forms the natural physical basis of investigation, although the older method of determining a distribution of pressure-stress throughout the fluid and examining how it affects the cores is still possible; that stress, however, is not simply transmitted, as it has to maintain the changes of velocity of the various portions of the fluid. But if the vortices have no solid cores we are at a loss to know where even this pressure can be considered as applied to them; if we follow up the stress, we lose the vortex; yet a fluid vortex can nevertheless illustrate an atom of matter, and we can consider such atoms as exerting mutual forces, only these forces cannot be considered as transmitted through the agency of fluid pressure. The reason is that the vortex cannot now be identified with a mere core bounded by a definite surface, but is essentially a configuration of motion extending throughout the medium.

Thus we are again in face of the fundamental question whether all attempts to

[1] We may compare G. W. Hill's more recent introduction of the idea of permanent orbits into physical astronomy.

represent the mechanical interactions of electro-dynamic systems, as transmitted from point to point by means of simple stress, are not doomed to failure; whether they do not, in fact, introduce unnecessary and insurmountable difficulty into the theory. The idea of identifying an atom with a state of strain or motion, pervading the region of the æther around its nucleus, appears to demand wider views as to what constitutes dynamical transmission. The idea that any small portion of the primordial medium can be isolated, by merely introducing tractions acting over its surface and transmitted from the surrounding parts, is no longer appropriate or consistent: a part of the dynamical disturbance in that element of the medium is on this hypothesis already classified as belonging to, and carried along with, atoms that are outside it but in its neighbourhood—and this part must not be counted twice over. The law of Poynting relating to the paths of the transmission of energy is known to hold in its simple form only when the electric charges or currents are in a steady state; when they are changing their positions or configurations their own fields of intrinsic energy are carried along with them.

It is not surprising, considering the previous British familiarity with this order of ideas, that the significance for general physics of Helmholtz's doctrine of vortices was eagerly developed in this country, in the form in which it became embodied through Lord Kelvin's famous illustration of the constitution of matter, as consisting of atoms with separate existence and mutual interactions. This vortex-atom theory has been a main source of physical suggestion because it presents, on a simple basis, a dynamical picture of an ideal material system, atomically constituted, which could go on automatically without extraneous support. The value of such a picture may be held to lie, not in any supposition that this is the mechanism of the actual world laid bare, but in the vivid illustration it affords of the fundamental postulate of physical science, that mechanical phenomena are not parts of a scheme too involved for us to explore, but rather present themselves in definite and consistent correlations, which we are able to disentangle and apprehend with continually increasing precision.

It would be an interesting question to trace the origin of our preference for a theory of transmission of physical action over one of direct action at a distance. It may be held that it rests on the same order of ideas as supplies our conception of force; that the notion of effort which we associate with change of the motion of a body involves the idea of a mechanical connection through which that effort is applied. The mere idea of a transmitting medium would then be no more an ultimate foundation for physical explanation than that of force itself. Our choice between direct distance action and mediate transmission would thus be dictated by the relative simplicity and coherence of the accounts they give of the phenomena: this is, in fact, the basis on which Maxwell's theory had to be judged until Hertz detected the actual working of the medium. Instantaneous transmission is to all intents action at a distance, except in so far as the law of action may be more easily formulated in terms of the medium than in a direct geometrical statement.

In connection with these questions it may be permitted to refer to the eloquent and weighty address recently delivered by M. Poincaré to the International Congress of Physics. M. Poincaré accepts the principle of Least Action as a reliable basis for the formulation of physical theory, but he imposes the condition that the results must satisfy the Newtonian law of equality of action and reaction between each pair of bodies concerned, considered by themselves; this, however, he would allow to be satisfied indirectly, if the effects could be traced across the intervening æther by stress, so that the tractions on the two sides of each ideal interface are equal and opposite.[1] As above argued, this view appears to exclude *ab initio* all atomic theories of the general type of vortex atoms, in which the energy of the atom is distributed throughout

[1] *Cf.* also Hertz on the electro-magnetic equations, § 12, *Wied. Ann.*, 1890. [The standpoint of Hertz's posthumous *Mechanik* approximates, however, to that here maintained.] The problem of merely replacing a system of forces by a statical stress is widely indeterminate, and therefore by itself unreal; the actual question is whether any such representation can be coordinated with existing dynamics.

the medium instead of being concentrated in a nucleus; and this remark seems to go to the root of the question. On the other hand, the position here asserted is that recent dynamical developments have permitted the extension of the principle of Action to systems involving permanent motions, whether obvious or latent, as part of their constitution; that on this wider basis the atom may itself involve a state of steady disturbance extending through the medium, instead of being only a local structure acting by push and pull. The possibilities of dynamical explanation are thus enlarged. The most definite type of model yet imagined of the physical interaction of atoms through the æther is, perhaps, that which takes the æther to be a rotationally elastic medium after the manner of MacCullagh and Rankine, and makes the ultimate atom include the nucleus of a permanent rotational strain-configuration, which as a whole may be called an electron. The question how far this is a legitimate and effective model stands by itself, apart from the dynamics which it illustrates; like all representations it can only cover a limited ground. For instance, it cannot claim to include the internal structure of the nucleus of an atom or even of an electron; for purposes of physical theory that problem can be put aside, it may even be treated as inscrutable. All that is needed is a postulate of free mobility of this nucleus through the æther. This is definitely hypothetical, but it is not an unreasonable postulate because a rotational æther has the properties of a perfect fluid medium except where differentially rotational motions are concerned, and so would not react on the motion of any structure moving through it except after the manner of an apparent change of inertia. It thus seems possible to hold that such a model forms an allowable representation of the dynamical activity of the æther, as distinguished from the complete constitution of the material nuclei between which that medium establishes connection.

At any rate, models of this nature have certainly been most helpful in Maxwell's hands towards the effective intuitive grasp of a scheme of relations as a whole, which might have proved too complex for abstract unravelment in detail. When a physical model of concealed dynamical processes has served this kind of purpose, when its content has been explored and estimated, and has become familiar through the introduction of new terms and ideas, then the ladder by which we have ascended may be kicked away, and the scheme of relations which the model embodied can stand forth in severely abstract form. Indeed many of the most fruitful branches of abstract mathematical analysis itself have owed their start in this way to concrete physical conceptions. This gradual transition into abstract statement of physical relations in fact amounts to retaining the essentials of our working models while eliminating the accidental elements involved in them; elements of the latter kind must always be present because otherwise the model would be identical with the thing which it represents, whereas we cannot expect to mentally grasp all aspects of the content of even the simplest phenomena. Yet the abstract standpoint is always attained through the concrete; and for purposes of instruction such models, properly guarded, do not perhaps ever lose their value: they are just as legitimate aids as geometrical diagrams, and they have the same kind of limitations. In Maxwell's words, 'for the sake of persons of these different types scientific truth should be presented in different forms, and should be regarded as equally scientific whether it appear in the robust form and the vivid colouring of a physical illustration, or in the tenuity and paleness of a symbolical expression.' The other side of the picture, the necessary incompleteness of even our legitimate images and modes of representation, comes out in the despairing opinion of Young ('Chromatics,' 1817), at a time when his faith in the undulatory theory of light had been eclipsed by Malus's discovery of the phenomena of polarisation by reflection, that this difficulty 'will probably long remain, to mortify the vanity of an ambitious philosophy, completely unresolved by any theory:' not many years afterwards the mystery was solved by Fresnel.

This process of removing the intellectual scaffolding by which our knowledge is reached, and preserving only the final formulæ which express the correlations of the directly observable things, may moreover readily be pushed too far. It asserts the conception that the universe is like an enclosed clock that is wound up to go, and that accordingly we can observe that it is going, and can see some of

its more superficial movements, but not much of them; that thus, by patient observation and use of analogy, we can compile, in merely tabular form, information as to the manner in which it works and is likely to go on working, at any rate for some time to come; but that any attempt to probe the underlying connection is illusory or illegitimate. As a theoretical precept this is admirable. It minimises the danger of our ignoring or forgetting the limitations of human faculty, which can only utilise the imperfect representations that the external world impresses on our senses. On the other hand such a reminder has rarely been required by the master minds of modern science, from Descartes and Newton onwards, whatever their theories may have been. Its danger as a dogma lies in its application. Who is to decide, without risk of error, what is essential fact and what is intellectual scaffolding? To which class does the atomic theory of matter belong? That is, indeed, one of the intangible things which it is suggested may be thrown overboard in sorting out and classifying our scientific possessions. Is the mental idea or image, which suggests, and alone can suggest, the experiment that adds to our concrete knowledge, less real than the bare phenomenal uniformity which it has revealed? Is it not, perhaps, more real in that the uniformities might not have been there in the absence of the mind to perceive them?

No time is now left for review of the methods of molecular dynamics. Here our knowledge is entirely confined to steady states of the molecular system: it is purely statical. In ordinary statics and the dynamics of undisturbed steady notions, the form of the energy function is the sufficient basis of the whole subject. This method is extended to thermo-dynamics by making use of the mechanically available energy of Rankine and Kelvin, which is a function of the bodily configuration and chemical constitution and temperature of the system, whose value cannot under any circumstances spontaneously increase, while it will diminish in any operation which is not reversible. In the statics of systems in equilibrium or in steady motion, this method of energy is a particular case of the method of Action; but in its extension to thermal statics it is made to include chemical as well as configurational changes, and a new point appears to arise. Whether we do or do not take it to be possible to trace the application of the principle of Action throughout the process of chemical combination of two molecules, we certainly here postulate that the static case of that principle, which applies to steady systems, can be extended across chemical combinations. The question is suggested whether extension would also be valid to transformations which involve vital processes. This seems to be still considered an open question by the best authorities. If it be decided in the negative a distinction is involved between vital and merely chemical processes.

It is now taken as established that vital activity cannot create energy, at any rate in the long run which is all that can from the nature of the case be tested. It seems not unreasonable to follow the analogy of chemical actions, and assert that it cannot in the long run increase the mechanical availability of energy—that is, considering the organism as an apparatus for transforming energy without being itself in the long run changed. But we cannot establish a Carnot cycle for a portion of an organism, nor can we do so for a limited period of time; there might be creation of availability acc mpanied by changes in the organism itself, but compensated by destruction and the inverse changes a long time afterwards. This amounts to asserting that where, as in a vital system or even in a simple molecular combination, we are unable to trace or even assert complete dynamical sequence, exact thermodynamic statements should be mainly confined to the activity of the existing organism as a whole; it may transform inorganic material without change of energy and without gain of availability, although any such statements would be inappropriate and unmeaning as regards the details of the processes that take place inside the organism itself.

In any case it would appear that there is small chance of reducing these questions to direct dynamics; we should rather regard Carnot's principle, which includes the law of uniformity of temperature and is the basis of the whole theory, as a property of statistical type confined to stable or permanent aggregations of matter. Thus no dynamical proof from molecular considerations could be regarded

as valid unless it explicitly restricted the argument to permanent systems; yet the conditions of permanency are unknown except in the simpler cases. The only mode of discussion that is yet possible is the method of dynamical statistics of molecules introduced by Maxwell. Now statistics is a method of arrangement rather than of demonstration. Every statistical argument requires to be verified by comparison with the facts, because it is of the essence of this method to take things as fortuitously distributed except in so far as we know the contrary; and we simply may not know essential facts to the contrary. For example, if the interaction of the æther or other cause produces no influence to the contrary, the presumption would be that the kinetic energy acquired by a molecule is, on the average, equally distributed among its various independent modes of motion, whether vibrational or translational. Assuming this type of distribution to be once established in a gaseous system, the dynamics of Boltzmann and Maxwell show that it must be permanent. But its assumption in the first instance is a result rather of the absence than of the presence of knowledge of the circumstances, and can be accepted only so far as it agrees with the facts; our knowledge of the facts of specific heat shows that it must be restricted to modes of motion that are homologous. In the words of Maxwell, when he first discovered in 1860, to his great surprise, that in a system of colliding rigid atoms the energy would always be equally divided between translatory and rotatory motions, it is only necessary to assume, in order to evade this unwelcome conclusion, that 'something essential to the complete statement of the physical theory of molecular encounters must have hitherto escaped us.'

Our survey thus tends to the result, that as regards the simple and uniform phenomena which involve activity of finite regions of the universal æther, theoretical physics can lay claim to constructive functions, and can build up a definite scheme; but in the domain of matter the most that it can do is to accept the existence of such permanent molecular systems as present themselves to our notice, and fit together an outline plan of the more general and universal features in their activity. Our well-founded belief in the rationality of natural processes asserts the possibility of this, while admitting that the intimate details of atomic constitution are beyond our scrutiny and provide plenty of room for processes that transcend finite dynamical correlation.

The following Papers were read:—

1. *Note on M. Cremieu's Experiment. By* Prof. G. F. FitzGerald, *F.R.S.*

M. Cremieu has shown that, if his experimental methods can bear criticism as well as they seem to do, there is no induced electromotive force on a coil of wire surrounding a rotating disc when the strength of an electric charge on the disc is changing. He has deduced from this the conclusion that there is no magnetic induction through the disc due to the moving charge such as Rowland's experiments showed. This note is to point out that too little is known of the theory of the ethereal effects of a charge of electricity forced to move by mechanical actions for us to be quite sure that both M. Cremieu's and Rowland's observations may not be true—*i.e.*, that it is possible that a charge of electricity, while it is being accelerated by moving matter, may produce such an action on the surrounding ether as to neutralise the electric force that would otherwise be produced by the changing magnetic induction due to the moving charge.

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2. *On the Creeping of Liquids and the Surface Tension of Mixtures. By* Dr. F. T. Trouton, *F.R.S.*

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3. *On a Method of Investigating Correspondences between Spectra. By* Hugh Ramage.

The method is graphical; spectral lines are plotted as abscissæ, and the atomic weights of the elements, or functions of the atomic weights, as ordinates. Con-

necting lines are then drawn through homologous spectral lines. The spectra studied by the author in this way are chiefly those emitted by the metals in the oxyhydrogen and oxycoal gas flames. These spectra are much simpler than those of the same metals in the electric arc or spark, and may be regarded as the fundamental spectra of the metals. They are therefore the most suitable spectra for comparison.

As the flame spectra of the metals have not been fully investigated some lines have been selected, to make the diagrams more complete, from arc and spark spectra. In these cases the selection was made after a study of the character of the lines in these spectra. Later experimental work on flame spectra has confirmed the selection of some of these lines, and the work on the Zeeman effect, of Preston on magnesium, zinc, and cadmium, and of Lord Blythswood and Dr. Marchant on mercury, confirms it in the spectrum of the latter metal. The formulæ and work of Rydberg and of Kayser and Runge lead to the selection of the same lines in all cases, and with these formulæ as guides it is possible to extend the work to other lines and spectra. This has been done, but only to a limited extent at present. The diagrams exhibited were drawn—(1) from atomic weights and oscillation frequencies, and (2) from the squares of the atomic weights and oscillation frequencies.

The diagrams show very clearly that the spectra of similar elements are very closely related to one another. That the spectra of potassium, rubidium, and cæsium are more closely related to one another than to those of lithium and sodium, and that there is also a break between the spectrum of magnesium and those of zinc, cadmium, and mercury, and between that of aluminium and those of gallium, indium, and thallium.

The connecting lines of the diffuse subordinate series of potassium, rubidium, and cæsium approach in the more refrangible lines measured to straight lines, while those of the principal series are nearly straight lines in the second diagram.

The lines joining the homologous lines of doublets and triplets approach one another as the atomic weight decreases, and, in the second diagram, intersect in points near the line of zero atomic weight. These curves give exact information regarding the function of the atomic weight which determines the differences, in oscillation frequencies, between the lines in doublets and triplets.

Equations are given, after the form of Rydberg's, for the principal series of lithium and sodium and of potassium, rubidium, and cæsium, and the calculated numbers are in close agreement with the observed numbers.

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4. *Report on Radiation in a Magnetic Field.*—See Reports, p. 52.

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5. *An Experiment on Simultaneous Contrast.* *By* George J. Burch, *M.A., F.R.S.*

It is well known that white objects seen against a red background look greenish-blue, and orange against a blue background.

This phenomenon is shown in a striking manner in the following experiment due to Hering:—A small white disc is viewed with the left eye against a red background, and another similar disc is viewed against a blue background with the right eye. The discs are so placed as to occupy different positions in the field of view. The result, when the light has been properly adjusted, is that the observer sees an amethyst-blue disc and a topaz-yellow disc against a pale purple ground.

The reason of this is demonstrated by the author in the following experiment:—Two pieces of glass, one red and the other blue, are inserted in a stereoscope in place of the usual slide, each glass having two small squares of black paper on it. Viewed binocularly the four squares appear as two. In front of the instrument, but out of the direct line of sight, are two adjustable slits, and over the eye-lenses of the stereoscope are two diffraction gratings. The position of the slits is so arranged that the spectrum of the first order of the left-hand grating falls on the

right-hand square, and that of the right-hand grating on the left-hand square, the two spectra, which can be adjusted to the same intensity, being thus seen side by side, one with the left eye on a red ground, and the other with the right eye on a blue ground. The red glass produces partial red blindness of the left eye, and the spectrum seen by it lacks red, the other colours being unaltered. And for a similar reason the spectrum seen by the right eye lacks blue, the effect being more noticeable owing to the contrast of sensation in the two eyes. In the author's opinion this experiment affords further confirmation of the views of Scherffer, Darwin, and Young in regard to contrast.

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6. *A Quartz-Calcite Symmetrical Doublet.* *By* J. W. GIFFORD.

The difficulty in constructing lenses of crystals consists chiefly in the double refraction, which causes confusion. As quartz is a positive, and calcite a negative, crystal, they tend to correct one another, although the separation of the lines in quartz is only one-twentieth of that in calcite. Both lenses are cut with their axes corresponding to the axes of the crystals. The wave-length situated at the point of greatest actinic activity is about 2748, as found by averaging the position of bright lines of the principal spectra as follows:

Substance	W. L. Centre of maximum effect	Substance	W. L. Centre of maximum effect
Air	3310	Lead	3051
Iron	2655	Tin	2571
Magnesium	2930	Copper	2444
Zinc	2557	Silver	2465
Cadmium	3023		
Arsenic	2600		2760·6 = Average.

This was equalised with W. L. 5607 or the centre of visual activity. The indices were determined by using prisms polished on three sides, and by averaging the observations, so that the angle of the prism might be taken as exactly 60. The temperature was 59° Fahrenheit.

W. L.	Element	Quartz	Calcite
		Ordinary Ray	
5893	Na	1·5442497	1·6583555
5607	Pb	1·5454613	1·6604548
2839	Cd	1·5837464	1·7335025
2748	Cd	1·5875286	1·7415041
		Extraordinary Ray	
5893	D	1·5533652	1·4863913
5607	Pb	1·5546100	1·4873448
2839	Cd	1·5942126	1·5194123
2748	Cd	1·5981316	1·5226616

In calculating the radii the formula $W = \frac{S'}{R}$ was used, with the following results for unity:

1	W = ∞	R = ·4213664	S & R′ = ·2026631	S′ = ∞
2	„ 5	„ ·33070931	„ ·1809102	„ 1·6854657
3	„ 4	„ ·3160248	„ ·1746611	„ 1·2640993
4	„ 3·5	„ ·3009760	„ ·1699643	„ 1·0534160
5	„ 3	„ ·2809109	„ ·1633743	„ ·8427328
6	„ 2·5	„ ·2528198	„ ·1534578	„ ·6320496
7	„ 2	„ ·2106832	„ ·1368452	„ ·4213664
8	„ 1·5	„ ·1404555	„ ·1032977	„ ·2106832

No 3 × by 25 was taken, and the focus = 12″. The angle made with the axis by the ray in Calcite varied from 2° 47′ 26″ to 1° 14′ 10″ for W. L. 2748 and from 2° 36′ 26″ to 1° 9′ 17″ for W. L. 5607, and the spherical aberration of the combination for W. L. 2748 was −·051337, and for W. L. 5607 was −·069809. No. 5 would probably have covered better without introducing too much double refraction.

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7. *The Production of an Artificial Light of the same Character as Daylight. By* ARTHUR DUFTON, *M.A., B.Sc., and* WALTER M. GARDNER, *Bradford Technical College.*

It is a matter of common experience that many colours alter in appearance when seen by artificial light.

The extent to which colours may vary under different illumination is perhaps not commonly known, but is well illustrated by the range of dyed cloths exhibited. Amongst other patterns, one which is green by daylight becomes red-brown by gaslight; a violet changes to purple; a grey to heliotrope; a shade of tan to a brick red. Particularly striking is a pattern woven from specially dyed yarns, which appears a uniform green colour by daylight, but which is figured by gaslight. Seen by the light of the electric arc, the patterns show similar but less marked changes.

It may be of interest to indicate briefly how such peculiar changes of colour arise. The colour of a body depends in the first place on the nature of the incident light. In monochromatic red light a red appears much the same as in daylight, but a yellow changes to red, a green is almost black, while blues and violets become red.

Gaslight shows a continuous spectrum from red to violet, but compared with daylight is of a strong orange colour due to an excess of rays in the red, orange, and yellow It does not, however, necessarily result that all colours appear redder by gaslight. It is, indeed, well known that the majority of colours change little by gaslight. This is due to the adaptability of the eye; if the light becomes redder, the eye becomes less sensitive to red; if the light is deficient in green, the eye becomes more sensitive to green. Persons working by gaslight soon cease to notice its intense orange colour. It results that a grey produced by mixture of black and white appears grey under any illumination, and simple colours, such as reds, oranges, and some greens giving light confined practically to one part of the spectrum, undergo little change.

Generally, however, the colour of a body is due to a mixture of light from different parts of the spectrum. All violet colours are transparent, not only for violet, but also for blue and red light; all blues transmit not only blue, violet, and green light, but also more or less red. Consequently, whenever a blue or violet is used in the production of what is called by artists a 'tertiary' colour, the general result is a colour having bright bands in different parts of the spectrum. A mixture of red, blue, and yellow to produce a neutral grey will show bright bands in the red and green—complementary colours, resulting in a proportion of white light. According to the exact position and intensity of these bands the grey will become redder or greener or may even remain unchanged by gaslight.

Generally colours become redder under artificial light. This is due not merely to the redder character of artificial lights as compared with daylight, but to the peculiar transparency of colouring matters for red light. Among reds and yellow, we have many theoretically perfect colouring matters—a perfect yellow being one having sharp absorption in the violet and blue, and perfect transparency for green, yellow, orange, and red rays. A perfect blue would be transparent for violet, blue, and green, and opaque for the rest of the spectrum.

Apparently such a blue can only be obtained by means of cupric salts. All other blue dyes and pigments we have examined agree in being more or less transparent for red light. Even greens transmit some red. This peculiar transparency of colours for red light is of primary importance in colour-matching. All

dyers know how persistent is the tendency to the development of red in the production of compound shades.

The need of an artificial light which should so closely resemble daylight as to show colours in their true relationship has long been felt by workers in colour. At present the electric arc light is largely used for colour work, but, as we have seen, it is far from satisfactory.

The peculiar character of daylight is due essentially to the modification produced by the atmosphere in the light from the sun. Light from a north sky as usually adopted for colour work is deficient in red, orange, and yellow rays, and consequently the light from a clear north sky is intensely blue.

Starting with the electric arc light as being nearest daylight in character, we have attempted to imitate by direct absorption the effect produced by scattering in the atmosphere.

The light of an arc lamp consists of two distinct parts:—(1) The light from the glowing carbons; (2) the light of the arc itself, characterised by its richness in violet rays. In lamps of the enclosed arc type the length of arc is increased, and consequently such lamps give a light richer in violet rays. Although arc lights vary somewhat in the proportion of violet light, they all agree in being richer than daylight in the amount of red, orange, and yellow rays, compared with the amount of green and blue. Owing to the peculiar transparency of colours to red light already noticed, it is of primary importance that the proportion of red light should be carefully adjusted. Small variations in the amount of violet light are of minor importance, owing to the eye being less sensitive to such rays, and also because in mixing colours there is not the same tendency to develop a band of violet as we have seen occurs in the red, since yellow colours generally have complete absorption in the violet.

The required absorption of the less refrangible rays can be effected by means of blue cupric salts. A solution of copper sulphate shows strong absorption at the extreme red of the spectrum, the absorption extending with diminishing intensity into the green.

For practical purposes the light from the arc is modified by passage through pale blue glass coloured by means of copper. This coloured glass may conveniently take the form of a globe replacing the ordinary globe of the arc light.

FRIDAY, SEPTEMBER 7.

The following Papers were read:—

1. *On the Statistical Dynamics of Gas Theory as illustrated by Meteor Swarms and Optical Rays.* *By* Dr. J. Larmor, *F.R.S.*

Imagine a cloud of meteors pursuing an orbit in space under outside attraction —in fact, in any conservative field of force. Let us consider a group of the meteors around a given central one. As they keep together their velocities are nearly the same. When the central meteor has passed into another part of the orbit, the surrounding region containing these same meteors will have altered in shape; it will in fact usually have become much elongated. If we merely count large and small meteors alike, we can define the density of their distribution in space in the neighbourhood of this group: it will be inversely as the volume occupied by them. Now consider their deviations from a mean velocity, say that of the central meteor of the group; we can draw from an origin a vector representing the velocity of each meteor, and the ends of these vectors will mark out a region in the velocity diagram whose shape and volume will represent the character and range of the deviation. It results from a very general proposition in dynamics that as the central meteor moves along its path the region occupied by the group of its neighbours multiplied by the corresponding region in their velocity diagram remains constant. Or we may say that the density at the group

considered, estimated by mere numbers, not by size, varies during its motion proportionally to the extent of the region on the velocity diagram which corresponds to it.

This is true whether mutual attractions of the meteors are sensibly effective or not; in fact, the generalised form of this proposition, together with a set of similar ones relating to the various partial groups of coordinates and velocity components, forms an equivalent of the fundamental law of Action which is the unique basis of dynamical theory.

Now, suppose that the mutual attractions are insensible, and that W is the potential of the conservative field: then for a single meteor of mass m and velocity v we have the energy $\frac{1}{2}mv^2 + m\mathrm{W}$ conserved: hence if δv_1 be the range of velocity at any point in the initial position, and δv_2 that at the corresponding point in any subsequent position of the group, we have $v_1\delta v_1 = v_2\delta v_2$, these positions remaining unvaried and the variation being due to different meteors passing through them. But if $\delta\omega_1$ and $\delta\omega_2$ are the initial and final conical angles of divergence of the velocity vectors, corresponding regions in the velocity diagram are of extents $\delta v_1 . v_1^2\delta\omega_1$ and $\delta v_2 . v_2^2\delta\omega_2$: these quantities are, therefore, in all cases proportional to the densities at the group in its two positions. In our present case of mutual attractions insensible, the volume density is thus proportional to $v\delta\omega$, because $v\delta v$ remains constant. Now the number of meteors that cross per unit time per unit area of a plane at right angles to the path of the central meteor is equal to this density multiplied by v: thus here it remains proportional to $v^2\delta\omega$, as the central meteor moves on. In the corpuscular formulation of geometrical optics this result carries the general law that the concentration in cross-section of a beam of light at different points of its path is proportional to the solid angular divergence of the rays multiplied by the square of the refractive index, which is also directly necessitated by thermodynamic principles; as a special case it limits the possible brightness of images in the well-known way.

In the moving stream of particles we have thus a quantity that is conserved in each group—namely, the ratio of the density at a group to the extent of the region or domain on the velocity diagram which corresponds to it; but this ratio may vary in any way from group to group along the stream, while there is no restriction on the velocities of the various groups. If two streams cross or interpenetrate each other, or interfere in other ways, all this will be upset owing to the collisions. Can we assign a statistical law of distribution of velocities that will remain permanent when streams, which can be thus arranged into nearly homogeneous groups, are crossing each other in all directions, so that we pass to a model of a gas? Maxwell showed that if the number of particles each of which has a total energy E is proportional to $e^{-h\mathrm{E}}$, where h is some constant (which defines the temperature), while the particles in each group range uniformly, except as regards this factor, with respect to distribution in position and velocity jointly, as above, then this will be the case. In fact, the chance of an encounter for particles of energies E and E′ will involve the product $e^{-h\mathrm{E}}e^{-h\mathrm{E}'}$ or $e^{-h(\mathrm{E}+\mathrm{E}')}$, and an encounter does not alter this total energy E + E′; while the domains or extents of range of two colliding groups each nearly homogeneous and estimated, as above, by deviation from a central particle in position and velocity jointly, will have the same product after the encounter as before by virtue of the Action principle. It follows that the statistical chances of encounter, which depend on this joint product, will be the same in the actual motion as are those of reversed encounter in the same motion statistically reversed. But if the motion of a swarm with velocities fortuitously directed can be thus statistically reversed, recovering its previous statistics, its molecular statistics must have become steady; in fact, we have in such a system just the same distribution of encountering groups in one direction as in the reverse direction: thus we have here one steady state. The same argument, indeed, shows that a distribution, such that the number per unit volume of particles whose velocity deviations correspond to a given region in the velocity diagram, is proportional to the extent of that region without this factor $e^{-h\mathrm{E}}$, will also be a steady one. This is the case of equable distribution in each group as regards only the position and velocity diagrams conjointly; but in this

case each value of the resultant velocity would occur with a frequency proportional to its square, and a factor such as e^{-hE} is required to keep down very high values. The generalisations by Boltzmann and Maxwell to internal degrees of freedom would lead us too far, the aim here proposed being merely concrete illustration of the very general but purely analytical argument that is fully set forth in the treatises of Watson, Burbury, and Boltzmann.

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2. *The Partition of Energy.* *By* G. H. BRYAN, *Sc.D., F.R.S.*[1]

Consider a system of particles in a field of force acting on one another with forces which are functions of the distances between them. If u, v, w are the velocity components of a particle of mass m, V, the potential energy of the system, the rate of increase of the component of kinetic energy, $\frac{1}{2} mu^2$, is given by

$$\frac{d}{dt}\left(\tfrac{1}{2} mu^2\right) = -u\frac{dV}{dx}$$

If the probability of any given motion of the system is equal to the probability of the reversed motion for given positions of the particles, then since equal positive and negative values of u are equally probable it appears that the mean rate of increase of $\frac{1}{2} mu^2$ estimated from probability considerations is zero. Now form the second differential coefficient of $\frac{1}{2} mu^2$ with respect to the time, which may be called the *acceleration* of this energy component. We obtain

$$\frac{d^2}{dt^2}\left(\tfrac{1}{2} mu^2\right) = \frac{1}{m}\left(\frac{dV}{dx}\right)^2 - u\Sigma\left(u\frac{d}{dx} + v\frac{d}{dy} + w\frac{d}{dz}\right)\frac{dV}{dx}$$

If we are given the probability that the coordinates of the system may be between given limits, then a condition for the stationary state is that the mean values of the accelerations of $\frac{1}{2} mv^2$, $\frac{1}{2} nw^2$, $\frac{1}{2} mw^2$ are zero. We thus obtain a system of equations of energy equilibrium for the system, which are sufficient to determine the mean values of the components of kinetic energy, provided the system is such that the mean values of products of velocities such as u_1v_1, u_1u_2, or u_1v_2 vanish. If this is not the case the conditions for a stationary state involve writing down further expressions for the accelerations or second differential coefficients of these velocity products, and equating their mean values to zero.

In this way the mean values of the squares and products of the velocity components for a stationary distribution are expressible in terms of the mean values of the squares of the force components, and the second differential coefficients of the potential energy with respect to the coordinates.

In this preliminary investigation the simplest possible illustrative examples are considered. For a system of two particles moving in a straight line and acting on one another with finite forces, the partition of energy follows Maxwell's law, and the mean product of the velocities vanishes if there is no external field of force. If there is a field of external force, this is no longer in general the case. We thus have some justification for the belief that in a polyatomic gas Maxwell's law of partition may no longer hold good, and this may account for the experimental result that this law is verified approximately only when translational and rotational energy are alone taken into account.

The principal advantage of studying the problem of energy-partition from the consideration of energy accelerations is that it leads to results for a perfectly reversible dynamical system somewhat analogous to the irreversible properties of temperature. The property that heat tends to flow from a hotter to a colder body is represented on this view by the property that when two stationary systems are allowed to act on one another, then if a certain inequality is satisfied energy is accelerated from one system to the other, and the direction of the acceleration is

[1] This paper will be published *in extenso* in the dedicatory volume to Professor Lorentz published by the University of Leiden.

determined by the sign of the inequality. This last is unaltered by reversing the velocity components of all the particles.

In order that a stationary distribution of energy may be *possible* certain conditions represented by inequalities must hold good, and further conditions, which may or may not be identical with these, must be satisfied in order that the distributions may be stable. These properties may perhaps have a physical interpretation in the notion that change of state takes place when the conditions in question cease to hold good. Finally, the fact that the Newtonian potential satisfies Laplace's equation may possibly give an exceptional character to the phenomena of energy-partition in the cosmic universe. It is also evident that expressions for the second differential coefficients of squares and products of velocity components may theoretically be written down for a dynamical system of the most general character, and applied to determine the partition of energy between the molecules and the ether.

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3. *Note on the Propagation of Electric Waves along Parallel Wires.* *By* Prof. W. B. MORTON, *M.A.*

In the 'Annalen der Physik' for June 1900, a very complete investigation of this problem has been published by G. Mie. He finds expressions for the wave-length and damping of the oscillations, involving a series of ascending powers of the ratio of radius of wires to distance apart. The object of this note is to point out that the approximate solution, in which the square of this ratio is neglected, can be very easily obtained from the known solution for a single wire, as worked out by Professor J. J. Thomson and by Sommerfeld. The formula for the damping agrees with that given by Heaviside's simple theory when Lord Rayleigh's high-frequency values are used for the resistance and inductance. Attention is called to an error in the formula for the K_0 function in the work of Thomson, Sommerfeld, and Mie, arising probably from an erratum in Heine's 'Kugelfunctionen.' It affects the numerical values worked out in Sommerfeld and Mie's papers.

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4. *On the Vector Potential of Electric Currents in a Field where Disturbances are propagated with Finite Velocity.* *By* S. H. BURBURY, *F.R.S.*

1. If $u'\,v'\,w'$ be the components of the total electric current at $x'\,y'\,z'$ in a homogeneous isotropic transparent medium, the components of vector potential F G H at any point $x\,y\,z$ at a given instant are usually defined as follows, $\mathrm{F} = \iiint \frac{u'}{r} dx'dy'dz = \int \frac{u'}{r} d\tau$ &c., where $r = \sqrt{(x'-x)^2 + (y'-y)^2 + (z'-z)^2}$ and the integration is over all space. Also $u'\,v'\,w'$ are the values of $u'\,v'\,w'$ at the given instant, and therefore all at the same instant. Hence follow Poisson's equations

$$\nabla^2 \mathrm{F}_{xyz} = -4\pi u_{xyz} \text{ \&c.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

2. If

$$\begin{aligned} a &= \frac{d\mathrm{H}}{dy} - \frac{d\mathrm{G}}{dz} \\ \beta &= \frac{d\mathrm{F}}{dz} - \frac{d\mathrm{H}}{dx} \\ \gamma &= \frac{d\mathrm{G}}{dx} - \frac{d\mathrm{F}}{dy} \end{aligned} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Then

$$\frac{d\gamma}{dy} - \frac{d\beta}{dz} = -\nabla^2 \mathrm{F} + \frac{d}{dx}\left(\frac{d\mathrm{F}}{dx} + \frac{d\mathrm{G}}{dy} + \frac{d\mathrm{H}}{dz}\right).$$

and if we assume

$$\frac{du'}{dx}+\frac{dv'}{dy}+\frac{dw'}{dz}=0,$$

and therefore

$$\frac{dF}{dx}+\frac{dG}{dy}+\frac{dH}{dz}=0 \text{ everywhere,}$$

we have

$$\frac{d\gamma}{dy}-\frac{d\beta}{dz}=-\nabla^2 F=4\pi u. \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Hence is deduced

$$\nabla^2 F=\frac{K}{4\pi}\frac{d^2F}{dt^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where $V=\frac{1}{\sqrt{K}}$ is the velocity of propagation of a disturbance. Also $\frac{1}{2}(Fu+Gv+Hw)$ is the energy per unit of volume at $x\ y\ z$. . . . . (5)

3. The theory in this form is open to objection. If u', the current at $x'\ y'\ z'$, changes with the time, we have a corresponding change of F given by $\frac{dF}{du'}=\frac{1}{r}$. But owing to (4) no physical quantity at $x\ y\ z$ can be immediately affected by the change at $x'\ y'\ z'$. The change can have no effect whatever at $x\ y\ z$ till after the expiration of the time $\frac{r}{V}$. If therefore F be any physical quantity, we must have $\frac{dF}{du'}=0$, which is inconsistent with our definition. If F be not a physical quantity, Fu cannot denote energy, which is inconsistent with (5).

4. The fact that V is very great, and $\frac{r}{V}$ very small, does not meet the difficulty, because $\frac{r}{V}\frac{du'}{dt}$ is not generally small.

5. It is proposed to substitute for u', the current at $x'\ y'\ z'$ at the given instant, u_t' the current which did exist at $x'\ y'\ z'$ $\frac{r}{V}$ seconds ago, so that our definition will be $F_t=\int\frac{u'_t}{r}d\tau$. F_t is used by way of distinction from F. In this form of F the objections above taken cease to have effect.

As u' and all its derived coefficients according to the time are supposed finite, we may write $u'_t=u'-\frac{r}{V}\frac{du'}{dt}+\frac{1}{2}\frac{r^2}{V^2}\frac{d^2u'}{dt^2}$, &c., or symbolically, for convenience only,

$$u'_t=\epsilon^{-\frac{r}{V}\frac{d}{dt}}u'$$

$$F_t=\int d\tau\frac{1}{r}\epsilon^{-\frac{r}{V}\frac{d}{dt}}u' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

6. It is shown that, *primâ facie*, F_t, G_t, H_t, so defined, satisfy the differential equations (1) as well as do the ordinary F G H. So as regards the differential equations the proposed substitution makes no difference in form to the theory.

7. An objection is considered that F and F_t cannot both satisfy Poisson's equations (1) because if they did we should have $\nabla^2F=\nabla^2F_t$, and this cannot, it is said, be true because

$$F=F_t+\int dt\frac{1}{V}\frac{du'}{dt}-\frac{1}{2}\int dt\frac{r}{V^2}\frac{d^2u'}{dt^2}+\frac{1}{2.3}\int dt\frac{r^2}{V^3}\frac{d^3u'}{dt^3}\ \&c.$$

and since

$$\left.\begin{array}{l}\nabla^2 r \neq 0\\ \nabla^2 r^2 \neq 0\end{array}\right\} \text{when } r=0,\ \nabla^2 F = \nabla^2 F_t \text{ is not true.}$$

If the objection be valid, it is not evident whether we should use F or F_t.

8. But Poisson's equation requires only that, however small be the radius 'a' of a sphere described about $x\ y\ z$,

$$\int_0^a 4\pi r^2 \nabla^2 F dr = -4\pi \int_0^a 4\pi r^2 u dr$$

and that is satisfied by both F and F_t. For the purpose of Poisson's equation we may use $\nabla^2 F$ and $\nabla^2 F_t$ as interchangeable.

9. Since $\frac{du'}{dt}$ has different values for different waves, F_t should be the sum of a number of terms of the form (6), each corresponding to a wave-length.

10. *Et seq.*—A calculation is made of the effect of using F_t instead of F in case of a disturbance spreading in spherical waves from a source.

SATURDAY, SEPTEMBER 8.

The following Reports and Papers were read:—

1. *Report on Determining the Magnetic Force on Board Ship.*
See Reports, p. 45.

2. *Final Report on the Sizes of Pages of Scientific Periodicals.*
See Reports, p. 45.

3. *On the Similarity of Effect of Electrical Stimulus on Inorganic and Living Substances. By* JAGADIS CHUNDER BOSE, *M.A., D.Sc., Professor of Physical Science, Presidency College, Calcutta.*

If we take a piece of living tissue, say a piece of muscle, and subject it to an electric stimulus, there will be produced a contraction; the stimulus causes a rearrangement of the particles of the living substance by which the form of muscle is changed. On the cessation of stimulus the muscle, recovering from the molecular strain, gradually attains its original shape. The effect of stimulus on nerves is, however, not apparent; there is no change of form. The molecular disturbance due to stimulus can, however, be detected in an indirect manner from certain electromotive variations that are produced. If now a mass of metallic filings be taken and subjected to electric shocks, there is no visible change. The substance appears to be irresponsive or dead to stimulus. Are inorganic substances then really irresponsive? Could this apparent want of response not be due after all to our inability to detect the profound molecular changes that may have nevertheless taken place in the substance under the action of stimulus? In nerves it is seen that the molecular changes can only be detected indirectly by an electric method.

The author describes an electric method based on the variation of conductivity, by which the molecular change due to an electric stimulus in an inorganic substance is detected and measured. Curves are in this manner obtained with the conductivity variation (proportional to molecular effect) as ordinates, and the time of exposure to the stimulus or the time of recovery from the effect of stimulus as abscissæ.

It is next shown that the effect on matter of electric stimulus, of widely varying

frequencies, is a continuous one. There is also a continuity of effect on all forms of inorganic matter, similar effects being produced not only (1) in all elementary substances—metals, non-metals, and metalloids—but also (2) in metallic compounds, such as the chlorides, bromides, iodides, oxides, and sulphides.

Comparisons are next made of the molecular response in both inorganic and living substances under varying conditions:—

1. On the effect of moderate stimulus.
2. On the effect of maximum stimulus.
3. On the effect of superposition of medium stimuli—(*a*) effect due to slow intermittence; (*b*) tetanic effect due to rapid intermittence.
4. On the opposite effect due to strong and feeble stimulus.
5. On the physical theory of 'fatigue' in inorganic and living substances.
6. On the various means of rapidly removing fatigue.
7. On the effect of injection of various substances which act as 'poisons.'

In all the above cases the curves for both living and inorganic substances are found to be similar.

The author next explains a theory of vision, and describes an artificial retina; the various effects of radiation on this artificial retina explain many obscure phenomena of vision.

Parallel experiments are then described with the artificial and the real retina:—

1. On the effect of short exposure to the action of radiation.
2. On the effect of intermittent radiation; on the question of the presence or absence of 'flicker' depending on the intensity of radiation and also on the rapidity of intermittence.
3. On the peculiarity of the visual sensation curve, as explained by the curve of effect on the artificial retina.
4. On the different elements of retinal fatigue.
5. On certain curious reversal effects.
6. On after-oscillation and visual recurrence.
7. On the novel phenomenon of binocular alternation of vision, and on the analysis of superposed images by alternate after-vision.
8. On the persistence of retinal oscillation, and its continuity with the phenomenon of memory.

In all the phenomena described above there is seen a remarkable similarity of effect of external stimulus on both living and non-living forms of matter. It is difficult to draw a line and say, 'Here the physical process ends and the physiological process begins,' or 'These are the lines of demarcation that separate the physical, the physiological, and the beginning of psychical processes.' No such arbitrary lines can be drawn, there being no abrupt break of continuity.

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4. *Wireless Telephony.* *By* Sir WILLIAM HENRY PREECE, *K.C.B.*, *F.R.S.*

The first experiments in this direction were made in the month of February 1894, across Loch Ness in the Highlands. On that occasion trials were made to determine the laws governing the transmission of Morse signals by the electromagnetic method of wireless telegraphy, which has formed the subject of frequent reports to this Section since 1884; two parallel wires well earthed were taken, one on each side of the lake, and arrangements were made by means of which the wires could be systematically shortened with a view of ascertaining the minimum length necessary to record satisfactory signals. It occurred to Mr. Gavey, who was experimenting, to compare telephonic with telegraphic signals, *i.e.*, to ascertain whether articulate speech could be maintained under the same conditions as Morse signalling. The trials showed that it was possible to exchange speech across the Loch at an average distance of 1·3 mile between the parallel wires when the length of the wires themselves was reduced to four miles on each side of the water.

What led to this train of thought was the fact that although the volume of telegraphic current was immensely greater than that of a telephonic current, whenever, through want of balance as a loop, disturbance was evident then telephonic cross-talk was also manifest. In other words, a weak telephonic current was apparently as powerful a disturber as a strong telegraphic one.

The sensation created in 1897 by Mr. Marconi's application of Hertzian waves, distracted attention from the more practical and older method. Mr. Evershed and Principal Oliver Lodge had, in the meantime, much advanced the system by introducing admirable call systems.

In 1899 I conducted some careful experiments on the Menai Straits which determined the fact that the maximum effects with telephones are produced when the parallel wires are terminated by 'earth' plates in the sea itself. It became quite evident that the ordinary inductive effects are much enhanced by conductive effects through the water, and that in consequence shorter wires are practical. No special apparatus seems necessary. The ordinary telephonic transmitters and receivers were used without induction coils.

It became desirable to establish communication between the islands or rocks known as the Skerries and the mainland of Anglesey, and it was determined to do this by means of wireless telephony. The lighthouse at the Skerries was wanted to be in communication with the coastguard station at Cemlyn. A wire 750 yards in length was erected along the Skerries, and on the mainland one of three and a half miles from a point opposite the Skerries to Cemlyn. Each line terminates by an earth plate into the sea. The average distance between the parallel portions of the two wires is 2·8 miles. Telephonic communication is readily maintained and the service is a good one.

Further experiments with wireless telephony have recently been made by Mr. Gavey between Rathlin Island, on the north coast of Ireland, and the mainland. The east and west portions of the island of Rathlin are about eight miles from the mainland, but a tongue of land projects southward to within a distance of four miles. Communication was required between the lighthouse near the north-eastern corner of the island and the mainland, and the question for solution was whether an overhead line running the whole length of the island from east to west was necessary to obtain good communication, or whether a shorter line across the neck of the southern peninsula would serve. The preliminary experiments that have been made prove conclusively that communication, both telegraphic and telephonic, has been readily maintained by means of temporary wires established across the neck of the peninsula along the shorter line. Wireless telegraphy across the sea is now a practical and commercial system.

No experiments have yet been made with ships, but it would appear simple to speak by telephone between ship and ship or between ship and shore to considerable distances by means of a circuit formed of copper wire terminating at each end of the ship in the sea, passing over the top-masts and using simple telephones.

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5. *On the Apparent Emission of Cathode Rays from an Electrode at Zero Potential. By* CHARLES E. S. PHILLIPS.

It has been noticed by many people who work with X-ray or other vacuum bulbs that numerous bright green patches occasionally appear upon the inner surface of the glass walls of a bulb while a discharge is passing, especially during the process of exhaustion.

These green flecks vary considerably from time to time in shape as well as in position, and efforts have been made to connect their existence either with want of uniformity in the composition of the glass or with irregularities in the surface of the negative electrode.

I have already, in another place,[1] given some account of an experiment made with the object of clearing up this uncertainty, and now beg to supplement that

[1] *Electrician*, 41, 1898, pp. 425, 426.

work with the following observations as to the cause of the phenomenon. The experiment just referred to consisted in using a pivoted disc of aluminium as the negative electrode in a bulb containing rarefied air, so that when green patches appeared a rotational movement of the disc (actuated by means of an external magnet) would show whether the patches of green moved in a corresponding manner or not. It was seen that they did so move.

A distinct feature of the experiment, however, consisted in ascertaining whether those flecks which persisted after the discharge had ceased were still sensitive to movements of the cathode. This also was found to be the case. The proof, therefore, that the green patches were associated with an emission from the cathode appeared complete.

But it was further noticed that subsequently to the passage of a discharge, and even when either or both of the electrodes were connected to earth, still the green flecks were easily visible upon the glass walls of the bulb, and continued to move as before when the cathode was rotated.

This was apparently a case in which cathode rays were emitted from an electrode at zero potential.

I do not know that any explanation of this effect has so far been offered, and I therefore venture to bring forward the following suggestions, supported by further experiments.

When a piece of metal is placed in a rarefied atmosphere and made the negative pole for an electrical discharge passing across the attenuated gas, innumerable small bright specks of light appear over the surface of the metal. It was found convenient in my particular case to use an *iron* electrode for observations of this effect, because it had the advantage of being readily magnetisable from without. The addition of a similar iron electrode to act as the anode determined the shape of the magnetic field. With such an apparatus it could be seen that the bright spots appeared principally upon the *cathode* while the discharge passed, and that the creation of a magnetic field between the electrodes made visible the individual luminous streams of gas emanating from those tiny points of light. The paths of these luminous streams, becoming bent by the action of the magnetic field, followed the direction of the lines of magnetic force and exhibited a tendency to become spiral in accordance with well-known laws. In this way a fine layer of sodium upon the anode was caused to fluoresce through the action of the negatively electrified particles beating down upon it. One was able, in fact, by this means to cast shadows of objects placed in the paths of the bent streams, and at a pressure considerably higher than that necessary for the production of the well-known cathode shadow effects. In the above case, however, the method served to clearly establish the fact that the bright points of light upon the surface of the cathode indicated the places from which the jets of gas originated.

The number of these jets became less as the exhaustion was continued, and individual streams were very clearly seen owing to the action of the magnetic field. When the discharge began to cause fluorescence in the glass of the bulb some green patches made their appearance, and, in some cases, when the cathode was magnetised a bright spot, which was previously judged to indicate the origin of a green patch upon the glass, would shift to a new position upon the electrode. In all such cases the corresponding patch also moved in a similar manner upon the glass.

At sufficiently high exhaustions the bright spots upon the electrode disappeared entirely, although green flecks were still visible upon the glass. But a movement as before of the electrode as well as its magnetisation gave results consistent with previous observations.

Under these conditions, when the discharge through the bulb was stopped green flecks were still visible for about ten seconds.

A positively charged body was brought up to the outside of the bulb and the patches brightened considerably. A negative charge similarly placed extinguished the flecks completely.

Finally, vacuum bulbs, such as X-ray lamps, &c., exhibiting green flecks while in operation, were generally found to deteriorate if laid aside for a month or two,

owing to an increase in the pressure of the contained gas. We see, therefore, that in the first place, the bright points of light upon the surface of the cathode are due to the emission of fine jets of gas; also that such jets, if negatively charged, may be made to cast shadows of objects suitably placed in their paths. It is at the same time clear that the green flecks referred to above are due, during the passage of a discharge, to these same jets of gas impinging upon the inner side of the glass walls, and that, under the conditions existing immediately subsequent to the passage of the discharge, streams of gas continue to be emitted from the pores of the electrodes. In spite of the fact that (with the electrodes connected to earth) these streams consist of unelectrified particles, they assume that property of ionisation during their passage across the space within the bulb which appears to be essential to the production of local fluorescence in the glass upon which they impinge.

This latter effect, while explaining the process by which a cathode emission may appear to originate at an electrode with no electrical charge upon it, is one to which I wish to draw especial attention, for there is reason to believe that the speed at which the individual particles, constituting the jets, move cannot exceed the rate at which sound is propagated in the rarefied medium.

It is therefore interesting to find that, under such circumstances, fluorescence was produced in the glass upon which the streams impinged.

As many of the observations referred to here were made during the course of an investigation into the diselectrifying action of magnetism now being carried out by myself at the Davy-Faraday Laboratory of the Royal Institution, I desire to express my indebtedness to the managers of that institution for the facilities which they have kindly placed at my disposal.

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6. *On Volta-electromotive Force of Alloys, and a Test for Chemical Union.* *By* Dr. G. Gore, *F.R.S.*

The question has been asked, 'How far does change in physical properties, such as electromotive force, &c., enable us to detect the existence of a compound in an alloy?' [1]

In reply to this I beg leave to say that whilst a *gain* of *mean* electromotive force of an alloy when used as a positive plate in a voltaic cell indicates that the constituents of the alloy are simply mixed together or dissolved in each other, a *loss* of *mean* electromotive force shows that they are chemically combined.

It is well known that simple dilution of an electrolyte usually *diminishes* the apparent electromotive force of a simple voltaic couple immersed in it. In a research, however, on 'The Relations of Volta-electromotive Force to Latent Heat, &c., of Electrolytes,' [2] I found that in eighteen out of nineteen cases of mere dilution of electrolytes with water, on measuring the apparent electromotive forces of a simple voltaic couple immersed—first, in water alone; secondly, in an undiluted electrolyte; and thirdly, in the same electrolyte diluted—a *gain* of *mean* electromotive force was produced by the diluted liquid above that of the *mean* amount as calculated from the separate amounts excited by the water alone and by the undiluted liquid. And I further found by a similar process in a subsequent research on 'A Method of Measuring Loss of Energy due to Chemical Union' [3] that when the ingredients of two electrolytes (such as an acid and an alkali) mixed together with strong chemical union, a *loss* instead of a *gain* of *mean* amount of electromotive force occurred; and that when two electrolytes mixed together without any degree of such union, as they are considered to do in cases of mere dilution, a *gain* of *mean* amount of such force nearly always took place. Similarly with metals dissolved in mercury and with solid alloys used as positive electrodes, the admixture of one metal with another when unattended by chemical union

[1] *Nature*, August 16, 1900, p. 369.
[2] *Phil. Mag.*, August 1891, p. 165.
[3] *Phil. Mag.*, January 1892, p. 28.

usually *increased* the *mean* electromotive force, but when attended by such union usually *decreased* it.[1]

Determinations of the amounts of apparent electromotive force yielded by various alloys of copper and zinc when used as positive plates in a voltaic cell have been made by A. P. Laurie,[2] and are given in the first three columns of the following table; and I have calculated from these numbers the *mean* electromotive forces and the percentage changes of such forces of the alloys, according to the method just referred to. They are as follows:—

Copper-zinc Alloy as a Positive Plate.

1. Parts of Zinc.	2. Parts of Copper.	3. Apparent E.M.F. in Volts.	4. Calculated mean E.M.F.	5. Change of mean E.M.F.	6. Per Cent.
	100·0	—·020			
25·0 +	75·0	—·020	+ ·1350	Loss ·1370	= 101·4
44·6 +	55·4	+ ·040	+ ·2566	,, ·2160	= 84·3
49·5 +	50·5	+ ·070	+ ·2860	,, ·2160	= 75·5
50·7 +	49·3	+ ·070	+ ·2946	,, ·2246	= 76·1
52·8 +	47·2	+ ·075	+ ·3070	,, ·232	= 75·5
53·9 +	46·1	+ ·065	+ ·3142	,, ·249	= 79·3
56·1 +	43·9	+ ·070	+ ·3279	,, ·257	= 78·3
58·3 +	41·7	+ ·080	+ ·3407	,, ·260	= 76·4
63·0 +	37·0	+ ·085	+ ·3700	,, ·285	= 77·0
63·5 +	36·5	+ ·085	+ ·3737	,, ·288	= 77·0
64·1 +	35·9	+ ·160	+ ·3775	,, ·216	= 57·5
* 66·2 +	33·8	+ ·530	+ ·3905	Gain ·140	= 35·9
66·8 +	33·2	+ ·520	+ ·3942	,, ·126	= 32·0
68·1 +	31·9	+ ·540	+ ·4022	,, ·138	= 34·3
69·7 +	30·3	+ ·570	+ ·4122	,, ·158	= 38·3
77·0 +	23·0	+ ·600	+ ·4574	,, ·143	= 31·3
83·6 +	16·4	+ ·580	+ ·4983	,, ·081	= 16·2
87·6 +	12·4	+ ·590	+ ·5231	,, ·067	= 12·8
96·5 +	3·5	+ ·590	+ ·5783	,, ·081	= 5·3
100·0 +		·600			

* $= Zn^2Cu$.

According to these numbers, whilst the *apparent* amounts of electromotive force, as shown in column 3, increased in nearly all cases, and with tolerable regularity, with the increased proportion of zinc in the alloys, the *mean* amounts, as shown in column 4, behaved very differently; thus with all the alloys containing more than 33·8 per cent. of copper (agreeing with the formula Zn^2Cu) there was a *loss* of mean electromotive force, and with less than 35·9 per cent. there was in all cases a *gain* (see column 5).

We may reasonably infer from the results obtained by dilution and mixture of electrolytes, and of metals with mercury,[1] that not only these, but the results obtained with *solid* alloys of copper and zinc, are largely, if not entirely, dependent upon two influences, viz., dilution and chemical union, the former tending to increase and the latter to decrease the mean electromotive force, and that had there been no cases of chemical union in the foregoing table there would have been none of *loss* of mean electromotive force. The effect of chemical union upon electromotive force appears to have been greater than that of dilution in all the mixtures which contained more than 33·8 per cent. of copper; and the numbers in column 4 indicate what the apparent amounts of

[1] See *Proc. Birm. Phil. Soc.*, vol. viii. pp. 63–138.
[2] *Journ. Chem. Soc.*, vol. liii. p. 104.

electromotive force would have been if there had been no changes caused either by dilution or by chemical union.

All the facts appear to be consistent with the theory that dilution increases and chemical union decreases the freedom of molecular movement.

7. *A Lecture-room Volt- and Amperemeter.* *By* Professor F. G. Baily.

A d'Arsonval galvanometer of moderate resistance is used, and a powerful lantern throws a conspicuous circle of light on to a large semi-transparent scale. A high resistance and a set of shunts allow of the measurement of electromotive forces, the scale being adjusted to read directly in volts or multiples, and a range of ·05 volt to 300 volts being obtained. By the omission of the high resistances the galvanometer and shunts may be used for ordinary purposes, and may be adjusted to measure thermo-electric forces. Currents from ·5 milliampere up to 30 amperes are measured by the difference of potential between the ends of a low resistance, two alternative resistances being used, and the range is improved by the use of resistances in series with the galvanometer. A tapping and a reversing key are fixed on the box.

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8. *On the Phosphorescent Glow in Gases.* *By* John B. B. Burke, *M.A.*

When a ring or electrodeless discharge is sent through a gas an after-glow is produced, at pressures within certain limits, in air varying between 0·7 mm. and 0·02 mm. A series of experiments was carried out to investigate the cause of this glow, and it was found that it was due to particles which do not carry a charge of electricity, but nevertheless produce conductivity in the gas as they pass through it. They are not stopped in their motion through charged wire-gauze electrodes, nor by an electromotive force, and yet cause a current to pass between two such electrodes situated lower down in a long vacuum tube. The glow diffuses through narrow brass tubing which is well earthed, proving that the glow itself does not carry a charge. When the diffusion takes place through a brass tap between two large bulbs the glow lasts three or four times as long in the one that the discharge has not passed through; and it was found that the glow in the former was destroyed instantaneously when a discharge was sent from a small induction coil between two electrodes in a side tube, showing that the glow was destroyed by the ionised gas.

The conductivity observed was probably due to the breaking up of the phosphorescent molecules by the ions produced by the spark as the glow moved through them.

MONDAY, SEPTEMBER 10.

The Section was divided into two Departments.

The following Reports and Papers were read:—

Department I.—Mathematics.

1. *Report on Tables of certain Mathematical Functions.*

See Reports, p. 46.

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2. *Report on the Present State of the Theory of Point-Groups.*

See Reports, p. 121.

3. *A Property of the Characteristic Symbolic Determinant of any* n *Quantics in* n *Variables.* *By* Major P. A. MacMahon, *F.R.S.*

If $a_{1x}^{\xi_1}, a_{2x}^{\xi_2}, \ldots a_{nx}^{\xi_n}$ be any n quantics in m variables in symbolic notation, so that

$$a_{1x} = a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \text{ and } a_{11}, a_{12}, \ldots a_{1n}$$

are umbræ, and

$$a_{1x}^{\xi_1}\, a_{2x}^{\xi_2} \ldots a_{nx}^{\xi_n} = \ldots + C_{\xi_1\xi_2\ldots\xi_n}\, x_1^{\xi_1}\, x_2^{\xi_2} \ldots x_n^{\xi_n} + \ldots$$

the paper is concerned with the sum

$$\Sigma\Sigma \ldots \Sigma\, C_{\xi_1\xi_2\ldots\xi_n}$$

the sum being for all positive integral values of $\xi_1, \xi_2, \ldots \xi_n$.

It is shown that if $f(\theta)$ denote the characteristic determinant of umbræ

$$\begin{vmatrix} a_{11}-\theta, & a_{12}, & \ldots \\ a_{21}, & a_{22}-\theta, & \ldots \\ \cdot & & \\ \cdot & \cdot & \\ \cdot & \cdot & \cdot \end{vmatrix}$$

the sum in question is

$$\frac{(-)^n}{f(1)}.$$

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4. *Sur les Relations entre la Géométrie Projective et la Mécanique.* *Par* M. Cyparissos Stéphanos.

Monsieur Stéphanos explique et précise le rôle de la géométrie projective dans la mécanique, et surtout en statique, en s'appuyant sur ce fait fondamental, peut-être non encore remarqué, que les seules transformations entre les coordonnées plückériennes d'une force qui respectent l'équilibre (c'est-à-dire, qui transforment un système quelconque de forces en équilibre, appliqué à un corps solide libre, en un autre système de forces également en équilibre) sont précisement des transformations linéaires et homogènes. Les transformations linéaires correspondent dans le plan aux homographies planes, tandis que dans l'espace elles correspondent soit à des homographies, soit à des corrélations.

Cela étant, les considérations et les méthodes de la géométrie projective (tant synthétique qu'analytique) sont indispensables en statique, et surtout en statique graphique, non seulement pour la coordination des résultats déjà connus, mais aussi pour l'assurement général et le progrès ultérieur de cette partie de la mécanique.

Enfin M. Stéphanos attire particulièrement l'attention sur les affinités de l'espace (transformations homographiques qui laissent invariable le plan à l'infini). Les affinités ont seules cette vertu remarquable de respecter fidèlement les diagrammes de la statique en faisant transformer point par point tout diagramme de forces en équilibre en un autre diagramme de forces également en équilibre. Par contre les transformations homographiques générales, aussi que les corrélations de l'espace, donnent immédiatement les lignes d'action des forces transformées, mais non leurs intensités, dont la détermination demande une construction auxiliaire.

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5. *The Use of Multiple Space in Applied Mathematics.* *By* H. S. Carslaw.

The ordinary method of Images may be used in the solution of problems in Electrostatics, &c., when the bounding planes meet at an angle $\frac{\pi}{m}$, but it fails

when the angle of inclination is $\frac{n\pi}{m}$ (n, m positive integers). Illustrations: $\frac{\pi}{m}$ ($m=1$, 2); $\frac{n\pi}{m}$($m=1$, $n=2$: $m=2$, $n=3$).

So far as I can learn it was first pointed out by Sommerfeld,[1] that a Riemann's surface might be here employed, and with the help of a Multiple Space, problems in Electrostatics, Electric Conduction, Hydrodynamics, Sound, and Conduction of Heat, in which the boundaries are planes meeting at an angle $\frac{n\pi}{m}$, have now been solved by Images.

The ideas involved may be illustrated by the potential problem in which the boundary is the semi-infinite plane $\theta=o$.

There is nothing to prevent us assuming that in this case the space with which we have to deal is defined by the range of $o<\theta<2\pi$, and the behaviour of the solution of the equation $\nabla^2 u=o$, outside that range need not concern us. It is found[2] that the periodic function

$$u=\frac{2}{\pi R}\tan^{-1}\sqrt{\frac{\sigma+\tau}{\sigma-\tau}},$$

where

$$R^2=r^2+r'^2-2rr'\cos(\theta-\theta')+(z-z')^2,$$

$$2rr'\cosh a_1=r^2+r'^2+(z-z')^2,$$

$$\sigma=\cosh\frac{a_1}{2},$$

$$\text{and } \tau=\cos\left(\frac{\theta-\theta'}{2}\right),$$

is a solution of the equation $\nabla^2 u=o$, with the required properties, its only singularity, in the range $-2\pi<\theta<2\pi$, being at (r', θ', z'). Calling this the solution corresponding to a pole at (θ'), if we associate with it that due to a pole at ($-\theta'$), we obtain a function, satisfying the boundary conditions, with only the one singularity in the range with which we are concerned.

Similar ideas enter into the solution of the other questions of this nature: where the ordinary Image method would reproduce singularities in the original space, by taking a function of a suitable period (a Riemann's space of the proper order) this result is avoided.

The problems in potential involving spherical boundaries may be solved by Inversion from the above. Hobson has considered,[3] by discussion in series, the direct solution of the cases of the circular disc and spherical bowl. By a method similar to Sommerfeld's, I have found the solution for the general case.

Taking the coordinate system employed by Hobson, in which the position of the point P is defined by

$$\rho=\log\frac{PA}{PB},$$

$$\theta=\angle APB,$$

$$\phi=\text{azimuthal angle},$$

the boundary $\theta=$constant, represents a portion of a spherical surface, of which the rim of the circular disc, whose diameter is AB, is the base. If we are dealing with the space bounded by an infinite plane with a circular hole, we define this region by

$$o<\theta<2\pi,$$

and associate with it that defined by

$$-2\pi<\theta<o.$$

Corresponding to the singularity at (θ'), we shall have one at ($-\theta'$).

[1] *Math Ann.* [2] *Proc. Lond. Math. Soc.*, xxviii., p. 413
[3] *Trans. Camb. Phil. Soc.*, vol. xviii.

When the boundary is the infinite plane with hemispherical bowl, we consider our Physical Space as given by

$$o<\theta<\frac{3\pi}{2},$$

and require three revolutions of the radius vector to complete our Multiple Space. The poles will now be at $(\pm\theta')$, $(\pm(3\pi+\theta'))$.

The general solution (of period $2n\pi$) required for such problems is given by

$$u=\frac{1}{n\pi\sqrt{2}}\sqrt{\cosh h\rho-\cos\theta.\cosh h\rho'-\cos\theta'}\int^{\infty}\frac{1}{\sqrt{\cosh ha-\cosh ha'}}\,\frac{\sinh h\frac{a}{n}}{\cosh h\frac{a}{n}-\cos\frac{\theta-\theta'}{n}}\,da,$$

where $\cos ha'=\cos h\rho\cos h\rho'-\sin h\rho\sin h\rho'\cos(\phi-\phi')$.

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6. *Determination of Successive High Primes. By* Lieutenant-Colonel Allan Cunningham, *R.E., and* H. J. Woodall, *A.R.C.Sc.*

A general method is described of determining, in a compendious manner, the *whole* of the primes within a given range. A table is given showing the *lowest* factors of all the numbers between $(2^{24}\mp 1020)$, *i.e.* between 16,776,196 and 16,778,236, which brings them all within the power of the existing large factor-tables. This determines the whole of the *High Primes* (117 in number) within the above range, as in table below:—

List of 117 *High Primes between* $(2^{24}\mp 1020)$.

16,776, . . .					16,777, . . .						16,778, . . .	
—	371	581	713	901	027	213	447	633	729	903	—	077
—	379	593	719	919	049	259	469	639	751	907	—	089
211	391	607	731	931	099	289	499	643	777	949	—	123
217	401	619	763	937	121	291	507	669	781	967	—	129
289	451	623	817	941	127	331	531	679	807	973	—	137
313	469	631	833	961	139	333	571	681	811	987	—	147
317	481	659	839	967	141	337	577	699	823	991	—	173
337	491	679	857	971	153	381	597	711	829	—	009	227
343	521	689	869	973	183	421	601	721	837	—	023	231
367	547	691	899	989	199	441	619	723	853	—	071	—

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7. *On the Construction of Magic Squares. By* Dr. J. Willis.

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8. *The Asyzygetic and Perpetuant Covariants of Systems of Binary Quantics. By* Major P. A. MacMahon, *F.R.S.*

The perpetuant theory connected with a single binary quantic has been completed as a consequence of the fact that all the asyzygetic seminvariants of given order are known and easily representable. The object of the present paper is to extend this knowledge to the seminvariant forms connected with a system of binary quantics. The method of Stroh is then applicable, and the complete theory can be established without difficulty.

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9. *On the Symbolism appropriate to the Study of Orthogonal and Boolian Invariant Systems which appertain to Binary and other Quantics.* *By* Major P. A. MacMahon, *F.R.S.*

It has been customary to study the theory of invariants by considering the invariants of the general linear substitution as of primary importance, and to pay comparatively little attention to the invariant forms connected with the orthogonal and Boolian substitutions. These latter substitutions are particular, and give rise to a number of forms which include those which arise from the general substitution; so that from one point of view the ordinary invariant theory is a particular case of the theory of orthogonal or of Boolian invariants. This is the view taken in this paper; the orthogonal and Boolian systems are studied by means of six invariant symbolic factors, and at any time the theory of Clebsch and Gordan and Aronhold can be derived by restricting attention to the two symbolic factors employed by them.

10. *A Quintic Curve cannot have more than fifteen real Points of Inflexion.* *By* A. B. Basset, *F.R.S.*

Zeuthen has shown [1] that not more than one third of the total number of points of inflexion that a quartic curve can have can be real. I propose to show that a similar proposition holds good in the case of a quintic curve.

A quintic curve cannot have more than six double points, nor more than forty-five points of inflexion.

Let A B C be the triangle of reference; and let A be a triple point composed of three *real* crunodes; and let B be a real crunode. Then the equation of the quintic is

$$a^2u_3 + a\gamma v_3 + \gamma^2 w_3 = 0 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where u_3, v_3, w_3 are binary cubics in β and γ.

Since each tangent at the triple point is composed of two real nodal tangents, the three tangents at this point count as six real stationary tangents. If, however, each tangent at the triple point has a contact of the third order with its respective branch (which is the highest contact that a tangent at a triple point on a quintic can have), each tangent counts three times as a real stationary tangent; and therefore the foregoing singularity reduces the number of *real* points of inflexion by nine. In this case, $v_3 = ku_3$, and (1) becomes

$$(a^2 + ka\gamma)u_3 + \gamma^2 w_3 = 0 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If each of the tangents at the crunode B has a contact of the fourth order with its respective branch (which is the highest contact which a tangent at a node on a quintic can have), each tangent counts three times as a stationary tangent, and therefore the foregoing singularity reduces the number of *real* points of inflexion by six.

We shall now show that these two singularities can coexist on a quintic.

Let

$$u_3 = (\lambda, \mu, \nu, \varpi \between \beta, \gamma)^3$$
$$w_3 = (l, m, n, p \between \beta, \gamma)^3$$

then (2) may be arranged in the form

$$\beta^3\{\lambda(a^2 + ka\gamma) + l\gamma^2\} + \beta^2\gamma\{\mu(a^2 + ka\gamma) + m\gamma^2\}$$
$$+ \beta\gamma^2\{\nu(a^2 + ka\gamma) + n\gamma^2\} + \varpi\gamma^3(a^2 + ka\gamma) + p\gamma^5 = 0 \quad . \quad . \quad (3)$$

If the nodal tangents at B have a contact of the fourth order with their respective branches

$$\mu = \rho\lambda, \ m = \rho l$$
$$\nu = \sigma\lambda, \ n = \sigma l$$

[1] *Math. Annalen*, 1875.

and (3) becomes

$$\{\lambda(a^2+ka\gamma)+l\gamma^2\}(\beta^3+\rho\beta^2\gamma+\sigma\beta\gamma^2)+\varpi\gamma^3(a^2+ka\gamma)+p\gamma^5=0 \quad . \qquad (4)$$

Equation (4) shows that the two foregoing singularities can coexist on a quintic. Moreover, there is nothing in the preceding equations of condition which prevents values being assigned to the constants which make the singularities at A and B *real*. Hence a quintic can have fifteen *real* points of inflexion. If, however, a quintic could have seventeen real points of inflexion, it would be possible to determine the constants so that C should be a *real* crunode. This would require that

$$p=0,\ l\sigma=0,\ \varpi k=0$$

in which case the quintic would break up into factors. Hence, fifteen is the maximum number of real points of inflexion that a quintic can have.

The fact that in the case of cubics, quartics, and quintics, only one third of the total number of points of inflexion can be real, leaves very little room to doubt that this law is universally true in the case of all algebraic curves.

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11. *On a Central-difference Interpolation Formula.* *By* Professor J. D. Everett, *F.R.S.*

The best-known formulæ for interpolation by 'central differences' are difficult to carry in the memory on account of their unsystematic aspect, one law being applicable to the odd and another to the even terms. This disadvantage does not attach to the formula here proposed.

Let u_0 and u_1 be two tabulated values between which a value is to be inserted at distance p from u_0 and q from u_1, so that $p+q=1$.

If we regard u_0 and u_1 as ordinates joined by a straight line cut in the required ratio, the ordinate of the point of section is qu_0+pu_1, which is a first approximation, exact when second differences vanish. A second approximation, exact when fourth differences vanish, is

$$qu_0+pu_1+\frac{(q+1)\,q\,(q-1)}{1\,.\,2\,.\,3}\Delta\delta u_0+\frac{(p+1)\,p\,(p-1)}{1\,.\,2\,.\,3}\Delta\delta u_1,$$

where in conformity with the notation explained in my paper of last year,[1] $\Delta\delta u_0$ $\Delta\delta u_1$ are the central differences of the second order corresponding respectively to u_0 u_1. This is a sufficient approximation when $\frac{1}{84}$ of the sum of the two central fourth differences is negligible. The complete formula is

$$\sum\frac{(q+r)\ .\ .\ .\ (q-r)}{1\ \ .\ .\ .\ .\ (2r+1)}\Delta^r\delta^r u_0+\sum\frac{(p+r)\ .\ .\ .\ (p-r)}{1\ \ .\ .\ .\ .\ (2r+1)}\Delta^r\delta^r u_1,$$

where the numerators and denominators are factorials, all having $2r+1$ factors with unity as the common difference.

The only novelty about the formula is the simplicity of its form. Each pair of terms is equivalent to a pair of terms in the second of the two central-difference formulæ of Stirling (*Methodus Differentialis*, Prop. 20), which is reproduced in some modern works; but that formula contains odd as well as even differences.

Since $q-1$ is $-p$, and $p-1$ is $-q$, the above formula may be written

$$qu_0+pu_1-\frac{pq}{6}\{(q+1)\Delta\delta u_0+(p+1)\Delta\delta u_1\}$$

$$+\frac{pq(p+1)(q+1)}{120}\{(q+2)\Delta^2\delta^2 u_0+(p+2)\Delta^2\delta^2 u_1\}+\ \&c.$$

which (in the absence of a table of numerical values of the coefficients) is perhaps

[1] See p. 645 in 1899 Report. The full paper is in the *Quarterly Journal of Mathematics* No. 124, 1900.

the best shape for practical calculation, and which furnishes an intermediate step in comparing the formula with Stirling's.

To prove the formula, note first that since the second central difference $\Delta\delta f(x)$ or $f(x+\Delta x)-2f(x)+f(x-\Delta x)$ is not altered by changing the sign of Δx, the value of $\Delta\delta f(q)$ is the same when the independent variable is p as when it is q.

Denote $\dfrac{(q+r)\ \ldots\ (q-r)}{1\ \ldots\ (2r+1)}$ by $\phi_r(q)$, so that $\phi_0(q)=q$, and $\phi_1(q)=\dfrac{(q+1)\,q\,(q-1)}{1\,.\,2\,.\,3}$

Then $\Delta\delta\phi_r(q)=\Delta\delta\phi_{r-1}(q)$.

Making p the independent variable, and denoting the value of our series by F (p), we have

$$\begin{aligned}F(p) &= qu_0+\phi_1(q)\Delta\delta u_0+\phi_2(q)\Delta^2\delta^2u_0+\&c.\\ &\quad +pu_1+\phi_1(p)\Delta\delta u_1+\phi_2(p)\Delta^2\delta^2u_1+\&c.\end{aligned}$$

$$\begin{aligned}\Delta\delta F(p) &= q\Delta\delta u_0+\phi_1(q)\Delta^2\delta^2u_0+\&c.\\ &\quad +p\Delta\delta u_1+\phi_1(p)\Delta^2\delta^2u_1+\&c.\\ \Delta^r\delta^r F(p) &= q\Delta^r\delta^r u_0+\&c.+p\Delta^r\delta^r u_1+\&c.\end{aligned}$$

Giving p the values 0 and 1, these become

$$\begin{array}{lll} F(0)=u_0, & \Delta\delta F(0)=\Delta\delta u_0, & \Delta^r\delta^r F(0)=\Delta^r\delta^r u_0.\\ F(1)=u_1, & \Delta\delta F(1)=\Delta\delta u_1, & \Delta^r\delta^r F(1)=\Delta^r\delta^r u_1.\end{array}$$

Hence F (p) coincides with u for all the tabulated values that can be built up from $u_0\,u_1$ and their even central differences to the r^{th} inclusive, that is for the $2r+2$ values of which u_0 and u_1 are the two central.

Moreover, when q is replaced by its value $1+p$, $F(p)$ has the standard parabolic form

$$A_0+A_1p+A_2p^2+\ \ldots\ +A_{2r+1}p^{2r+1}$$

containing $2r+2$ constants to be deduced from the given $2r+2$ tabulated values.

Since $\Delta^r\delta^r\phi_r(x)=\phi_0(x)=x$, we may write $\phi_r(x)=\Delta^{-r}\delta^{-r}x$, it being understood that in each inverse operation Δ^{-1} or δ^{-1}, the arbitrary constant is to be so taken as to make the result vanish with x. The formula may then be written

$$\begin{aligned}&\{q+(\Delta\delta)^{-1}q\,.\,\Delta\delta+(\Delta\delta)^{-2}q\,.\,(\Delta\delta)^2+\&c.\}\,u_0\\ &+\{p+(\Delta\delta^{-1}p\,.\,\Delta\delta+(\Delta\delta)^{-2}p\,.\,(\Delta\delta)^2+\&c.\}\,u_1.\end{aligned}$$

In like manner the ordinary interpolation formula

$$u_0+x\,\Delta u_0+\frac{x\,(x-1)}{1-2}\Delta^2u_0+\&c.$$

can be written

$$\{1+\Delta^{-1}1\,.\,\Delta+\Delta^{-2}1\,.\,\Delta^2+\&c.\}\,u_0;$$

and the formula for the same interpoland

$$u_0+x\delta u_0+\frac{x\,(x+1)}{1\,.\,2}\,\delta^2u_0+\&c.$$

can be written

$$\{1+\delta^{-1}1\,.\,\delta+\delta^{-2}1\,.\,\delta^2+\&c.\}u_0$$

Taylor's Theorem can be written

$$f(a+x)=(1+D^{-1}1\,.\,D+D^{-2}1\,.\,D^2+\&c.)f(a);$$

and the Binomial Theorem

$$(1+a)^x=(1+a\Delta^{-1}+a^2\Delta^{-2}+\&c.)\,1,$$

or

$$(1-a)^{-x}=(1+a\delta^{-1}+a^2\delta^{-2}+\&c.)\,1.$$

'Stirling's first' formula can be written $u_x - u_0$

$$= \{x + (\Delta\delta)^{-1} x \,.\, \Delta\delta + (\Delta\delta)^{-2} x \,.\, (\Delta\delta)^2 + \&c.\} \frac{\Delta + \delta}{2} u_0$$

$$+ \frac{\Delta + \delta}{2} \{(\Delta\delta)^{-1} x \,.\, \Delta\delta + (\Delta\delta)^{-2} x \,.\, (\Delta\delta) + \&c.\} u_0 ;$$

and 'Stirling's second,' with origin midway between u_0 and u_1, can be written

$$u_x = \{1 + (\Delta\delta)^{-1} 1 \,.\, \Delta\delta + (\Delta\delta)^{-2} 1 \,.\, (\Delta\delta)^2 + \&c.\} \frac{u_0 + u_1}{2}$$

$$+ \frac{\Delta^{-1} + \delta^{-1}}{2} \{1 + (\Delta\delta)^{-1} 1 \,.\, \Delta\delta + (\Delta\delta)^{-2} 1 \,.\, (\Delta\delta)^2 + \&c.\} \Delta u_0 ;$$

but here, instead of the inverse functions vanishing with x, Δ^{-1} is to vanish, for $x = \frac{1}{2}$ and δ^{-1} for $x = -\frac{1}{2}$.

12. *On Newton's Contributions to Central Difference Interpolation.* *By* Professor J. D. Everett, *F.R.S.*[1]

After a portion of the preceding abstract had been sent to the printer, I discovered that the two formulæ known as Stirling's are really due to Newton. They are given in Prop. 3 of Newton's 'Methodus Differentialis,' which is the closing one of a collection of minor treatises by Newton, published, with his permission, in 1711 by W. Jones, who states in the preface that this particular tract has been transcribed by him from a manuscript in Newton's handwriting.

I have also found in Lemma 5, which follows Prop. 40 of the third book of the 'Principia,' what is doubtless the earliest statement of the ordinary interpolation formula, now usually written

$$u_0 + x\Delta u_0 + \frac{x(x-1)}{1 \,.\, 2} \Delta^2 u_0 + \&c.$$

Newton gives it in a geometric shape, x, $x-1$, $x-2$, &c., being represented by lines, and he defines Δu_0 not as $u_1 - u$, but as $u_0 - u_1$, with a similar convention for higher differences, thus reversing the signs of all odd differences as compared with modern notation. Owing, I presume, to these disguises, the formula appears to have hitherto escaped recognition.

Department II.—Meteorology.

1. *Report on Meteorological Photography.*—See Reports, p. 56.

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2. *Report on Seismological Observations.*—See Reports, p. 59.

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3. *Fifth Report on the Use of Kites to obtain Meteorological Observations at Blue Hill Observatory, Massachusetts, U.S.A.* *By* A. Lawrence Rotch, *S.B., M.A., Director.*

Satisfactory progress has been made in the work since the report presented at the Dover meeting, and it is gratifying to observe that the method of exploring the air by means of instruments, recording graphically and lifted by kites, which was initiated at Blue Hill in 1894, is now being extensively used on the continent of Europe.

[1] Published *in extenso* in the *Journal of the Institute of Actuaries*, 1901.

By substituting larger wire as a flying line, and so diminishing relatively the wind resistance, and by employing kites that exert a greater component of lift, the average height of the flights thus far made during the present year has been increased 1,473 feet and the maximum height 3,350 feet over the corresponding heights in 1899. From January to the end of July, 1900, records were obtained during fifteen flights, the average height attained by the meteorograph being 8,875 feet above the adjacent ocean. Twelve of these flights exceeded 3,300 feet, ten exceeded 6,500 feet, six exceeded 9,800 feet, and two exceeded 13,000 feet. In the highest flight on July 21, six kites attached at intervals to four and three-quarter miles of steel wire lifted the meteorograph 15,170 feet above Blue Hill. This height of 15,800 feet above the sea surpasses the greatest altitude at which meteorological observations have been made from a balloon in America.[1] The records obtained during 1899 have been reduced by my assistant Mr. Clayton; a continuation of his studies of cyclonic and anticyclonic phenomena by means of kites was published as Bulletin No. 7 of the Observatory, and a summary appeared in 'Nature.'

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4. *Charts illustrating the Weather of the North Atlantic Ocean in the Winter of* 1898–99. *By* Captain CAMPBELL-HEPWORTH, *Meteorological Office.*

The Meteorological Council, having received a large amount of information from the logs of Atlantic steamships, have investigated the remarkably stormy weather experienced on that ocean in the winter of 1898–99, and charts for sixty consecutive days have been prepared exhibiting the atmospheric conditions over the sea and a great extent of the adjacent continents. The discussion has shown that while severe storms were of common occurrence on the ocean America was suffering an exceptionally cold season, while Europe enjoyed almost unexampled mildness.

Through the first few days the charts show comparatively undisturbed weather on the frequented ocean routes, but from Christmas onward hardly a day passed without more or less violent gales. The cyclonic depressions passed out to the Atlantic at various points between Florida and Labrador, some crossing quickly to the vicinity of the British Isles, others—and particularly the worst one in February—making very slow progress. Remarks in the logs testify to the tempestuous character of the season by frequent references to fierce, violent gales of hurricane force, mountainous, tremendous, and terrific seas, low temperatures, and blinding squalls of rain, hail, and snow. In the wild weather towards the close of December waves from 45 feet to 52 feet in height were reported, the s.s. *Parkman* was disabled, and other vessels sustained damage. At the beginning of January a hurricane, with terrific squalls, raged on and near the Bay of Biscay, resulting in various shipping casualties. From January 6 to 10 violent gales were continuous and damaged many ships. On the 23rd the s.s. *Turanian* broke her propeller shaft and sustained other damage during a cyclone with a mountainous cross sea running. The disturbance centred midway across the ocean on the 30th caused much disaster to shipping. In the hurricance, with terrific squalls and dangerous seas, the Cunarder *Pavonia* was disabled and the s.s. *Rossmore* sprang a leak.

The staunchest ships afloat were unable to withstand the frightful violence of the hurricanes of February, the powerful Cunarder *Lucania* and the Hamburg-American Co.'s *Fürst Bismarck* being delayed about three days, others a longer time. On February 2 the barometer fell, near the banks of Newfoundland, to 27·74 inches, and a rise of $\frac{1}{2}$ inch was registered on the R.M.S. *Lucania* in two hours. The Hamburg-American Co.'s liner *Bulgaria* was disabled on the 2nd, her rudder being broken. The *Pavonia, Bulgaria,* and *Rossmore* were now at the mercy of the elements, the *Pavonia's* boilers breaking adrift on the 3rd. Eventually the *Pavonia* and *Bulgaria* reached the Azores, but the *Rossmore* had to be abandoned to her fate.

[1] See *Science*, August 3, 1900.

The western side of the ocean was in great turmoil towards the close of the period under investigation, a depression skirting the American coast causing severe hurricanes and snowstorms, a great blizzard blocking up New York, and for twenty-four hours not a single vessel was able to pass Sandy Hook inward or outward.

On February 11 the barometer on the far north of the Atlantic was down to nearly 28½ inches, while at the same time there was a reading of 31·42 inches at Swift Current in Canada, believed to be the highest record known in America.

There was a very striking difference in the conditions obtaining on the continents on either side of the ocean. The American winter was characterised by almost persistent and severe cold in December and February, and to a less extent in January. As on the ocean February proved by far the worst month, the Weather Bureau at Washington stating that 'the overshadowing event of the month was the severe and widespread cold, culminating in a freeze that for duration and severity stands unparalleled in the history of the Weather Bureau.' Temperatures below zero Fahrenheit were registered over an extensive area, many places went below $-40°$, the lowest reported being $-61°$ at Fort Logan, Montana, on the night of the 10th. Severe frost extended southward to the Gulf of Mexico, both the swift-flowing rivers and Gulf water at the mouths of the Mississippi being frozen over.

Europe, on the other hand, had an exceedingly mild, open season, there being an entire absence of the usual January cold over the British Isles, while the temperatures recorded round February 10 were unprecedentedly high, Greenwich, Brussels, and Paris being higher by several degrees than ever before experienced in February. At Liège the thermometer rose to 70°·5, or 131½° above the American minimum of the following night. The exceptionally high temperatures extended eastward to the Ural Mountains, and even Davos Platz, an Alpine station at an elevation of 5,120 feet, had five days with afternoon maxima between 60° and 63°.

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5. *The Physical Effects of Winds in Towns and their Influence on Ventilation.* *By* J. W. Thomas.

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6. *A Novel Form of Mercurial Barometer.* *By* A. S. Davis.

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7. *The Rainfall of the Northern Counties of England.* *By* John Hopkinson, *F.R.Met.Soc., Assoc.Inst.C.E.*

This is the third of a series of papers on the rainfall of the English counties, an account of the rainfall of the South-Western Counties having been given at the Bristol Meeting of the Association in 1898, and the rainfall of the South-Eastern Counties having been similarly treated at Dover last year. The counties here considered as northern are Northumberland, Durham, Cumberland, Westmoreland, Lancashire, Yorkshire, Cheshire, Derby, Nottingham, and Lincoln. They comprise an area of 18,383 square miles, which is considerably over one-third that of England, and more than one-seventh that of the British Isles. The mean monthly rainfall for the ten years 1881 to 1890 at ninety-four stations in these counties has been computed, and the mean annual rainfall at 184 stations, being one to the nearest 100 square miles in each county. Thus, for example, the mean annual rainfall of the smallest county, Nottingham (837 square miles), is deduced from the records of eight stations, and that of the largest, Yorkshire (5,836 square miles), from the records of fifty-eight stations. Each Riding of Yorkshire has been similarly treated, except that there is one station short of the full number for the North Riding, one more than the right number being allotted to the East Riding in order to bring the total for the whole county correct.

The monthly and annual means for each county and for the whole area at the ninety-four stations are as follows:—

Mean Rainfall in the Northern Counties of England, 1881-90.

—	Northumberland, 11 stations	Durham, 7 stations	Cumberland, 6 stations	Westmoreland, 8 stations	Lancashire, 11 stations	Yorkshire, 26 stations	Cheshire, 7 stations	Derbyshire, 4 stations	Nottinghamshire, 3 stations	Lincolnshire, 11 stations	Mean, 94 stations
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
January .	2·23	2·02	5·68	5·69	3·35	2·88	2·35	3·61	1·94	1·72	3·04
February .	1·73	1·47	4·62	4·47	2·30	2·12	1·77	2·63	1·58	1·60	2·32
March . .	2·73	2·55	4·49	4·53	2·89	2·70	2·11	3·16	1·87	1·68	2·82
April . .	1·98	2·01	3·05	2·86	2·05	2·23	1·69	2·48	1·64	1·65	2·15
May . .	2·15	2·04	3·77	3·54	2·56	2·38	2 22	2·84	2·19	2·03	2·50
June . .	1·92	1·81	3·10	2·89	2·69	2·10	2·57	2·74	1·80	1·78	2·27
July . .	3·38	3·31	5·58	5·31	3·98	3·33	3·31	3·56	2 47	2·44	3·60
August . .	3·14	2·64	4·52	4·20	3·64	3·05	3·05	3·43	2·28	2·30	3·19
September .	2·86	2·30	5·58	4·90	3·67	2·70	3·02	3·25	1·94	2·18	3·14
October .	3·18	3·04	5·33	5·36	3·81	3·72	3·32	4·47	2·68	2·81	3·72
November . .	3·15	2·68	6·72	6·67	4·01	3·29	3·30	4·49	2·16	2·27	3·72
December .	2·58	2·27	5·48	5·46	3·38	2·85	2·63	3·57	1·89	1·84	3·09
Year . .	31·03	28·14	57·92	55·88	38·33	33·35	31·34	40·23	24·44	24·30	35·56

The annual means at the 184 stations are—Northumberland (19 stations), 30·78 ins.; Durham (11 stations), 27·22 ins.; Cumberland (15 stations), 70·02 ins.: Westmoreland, with Furness (10 stations), 57·90 ins.; Lancashire, without Furness (16 stations), 38·84 ins.; Yorkshire (58 stations), 33·73 ins.; Cheshire (11 stations), 32·37 ins.; Derby (10 stations), 36·79 ins.; Nottingham (8 stations), 25·25 ins.; and Lincoln (26 stations), 24·46 ins.; the mean for the whole area being 36·16 ins.

During the ten years 1881 to 1890 the rainfall in the North of England was rather less than that for the twenty-five years ending 1890 and that for the thirty years ending 1895. Forty stations (not less than two in any of the ten counties, and nine in Yorkshire) give a mean for the ten years 1881–90 of 38·54 ins.; for the twenty-five years 1866–90 of 39·80 ins.; and for the thirty years 1866–95 of 39·56 ins., the excess in this latter period thus being 1·02 in., or about 2⅔ per cent. over the mean fall at the same stations for the ten years 1881–90. The true mean for the 184 stations for the thirty years would probably be about 37 ins.

The mean fall for the thirty years at the forty stations in five-yearly periods was as follows:—For the first lustrum, 1866–70, 39·96 ins.; for the second, 1871–75, 40·12 ins.; for the third, 1876–80, 41·85 ins.; for the fourth, 1881–85, 41·19 ins.; for the fifth, 1886–90, 35·89 ins.; and for the sixth, 1891–95, 38·37 ins.

The rainfall in these counties follows the general rule of increase from east to west, except in the case of Cheshire, which has a smaller fall than either Lancashire, Derbyshire, or Yorkshire. This is probably due to the higher land in these counties. The rule is well exemplified in the Yorkshire Ridings, the mean annual fall in the East Riding (13 stations) being 26·48 ins.; in the North Riding (19 stations), 34·98 ins.; and in the West Riding (26 stations), 36·44 ins. There is also a marked decrease in the rainfall from north to south. Dividing the counties into three groups—North, Midland, and South—55 stations for the northern group, Northumberland, Durham, Cumberland, and Westmoreland, give an annual mean of 45·70 ins.; 74 stations for the middle group, Yorkshire and Lancashire,

give an annual mean of 34·83 ins.; and 55 stations for the southern group, Cheshire, Derbyshire, Nottingham, and Lincoln, give an annual mean of 26·58 ins. In the first group the driest months are April, mean 2·41 ins., and June, 2·36 ins.; in the second group the driest months are February, mean 2·17 ins., and April, 2·18 ins.; and in the third group the same months are the driest, February with a mean of 1·81 in., and April with 1·79 in. In the first group the wettest month is November, mean 4·60 ins.; in the second group the wettest month is October, mean 3·75 ins.; and in the third group the same month is the wettest, with a mean fall of 3·20 ins.

Nottingham and Lincoln are the driest counties throughout the year, except in February, when Durham is the driest, and in May, when Durham and Northumberland are drier than Nottingham. Cumberland and Westmoreland are the wettest throughout the year, Cumberland usually being the wetter of the two, but in January, March, October, November, and December the greatest difference between them is 0·05 in.

The mean and extreme annual rainfall at each station are given in the complete paper, with a map showing the position of the stations and their height above mean sea-level.

8. *Report on Meteorological Observations on Ben Nevis.*
See Reports, p. 46.

9. *Report on recording the Intensity of Solar Radiation.*
See Reports, p. 36.

10. *Report on establishing an Observatory on Mount Royal, Montreal.*
See Reports, p. 33.

TUESDAY, SEPTEMBER 11.

The following Report and Paper were read:—

1. *Report on Electrolysis and Electrochemistry.*—See Reports, p. 34.

2. *A Discussion on 'Ions' was opened by* Professor G. F. FitzGerald.

3. *The Radiation of a Black Body on the Electromagnetic Theory.* *By* H. C. Pocklington, *M.A., D.Sc.*

There are two methods that may be used to solve the problem, the direct and the indirect method, *viâ* Kirchhoff's laws. The latter seems preferable, as, on account of the freedom of choice of a substance, the mathematical work may be simplified by choosing the simplest kind of substance.

The substance here chosen is a gas, supposed to consist of atoms carrying electric charges. As a preliminary the question whether any result can be obtained from the data is investigated by the method of 'dimensions,' and the formulæ

$$R = k\theta^4 VQ^{-6}$$

and

$$dR = \theta^4 VQ^{-6} f\left(\frac{\theta\lambda}{Q^2}\right) \cdot \frac{d\lambda}{\lambda}$$

are found.

In any such formula the constants must have values neither very great nor very small. This is tested and found to be true. On attempting to carry out the mathematical calculations suggested, the radiation is found to vary as the temperature; a quite impossible result. Various modifications of the nature of the hypothetical gas selected are considered and dismissed as unsatisfactory.

The truth of the second law of thermodynamics is made to depend on the constancy of the ionic charges. This indicates that the constancy of the charge is due to some fundamental property of the ether. It seems probable that a complete solution of the problem requires a complete theory of matter and electricity.

WEDNESDAY, SEPTEMBER 12.

The following Report and Papers were read :—

1. *Report on Electrical Standards.*—See Reports, p. 53.

2. *A Form of Wheatstone's Bridge.* *By* E. H. Griffiths, *F.R.S.*

3. *Note on an Improved Standard Resistance Coil.* *By* R. S. Whipple. See Reports, p. 55.

4. *A Preliminary Research on Explosive Gaseous Mixtures.*[1] *By* J. E. Petavel.

Objects of the Research.—The primary object of the present research is to extend the work originally done by Bunsen at atmospheric pressures to initial pressures of one or two hundred atmospheres.

Both the maximum pressure of the explosion and the rate of change of the pressure are recorded. A long series of experiments, the result of which will shortly be published, having proved the very high thermal conductivity of compressed gases, it was important to obtain some further data with regard to the thermal properties of gases at the highest temperatures and pressures. It is also desirable that some further information with regard to the phenomena of dissociation at very high pressures should be obtained.

Finally, it is hoped that, from a practical point of view, the results will be of use as a contribution to the knowledge of thermodynamics.

In all heat engines the efficiency is greatly increased by the use of a wider temperature interval and higher pressures. Whereas mechanical difficulties, which, up to recently, had hindered progress in this direction, are gradually being overcome, the theoretical side of the question has not received all the attention it merits.

The Apparatus.—In order to gain some information with regard to the effect of the surface of the enclosure, three distinct enclosures are used :—

1° A spherical enclosure of 500 c.c. capacity (about 4 in. diameter).
2° A cylindrical enclosure, 27 in. long, also of 500 c.c. capacity.
3° A spherical enclosure of about 10,000 c.c. capacity.

The first two enclosures are calculated to withstand pressures up to two thousand atmospheres; the third, pressures up to two hundred atmospheres.

[1] The experiments have been carried out at the Davy-Faraday Laboratory of the Royal Institution. Part of the apparatus was provided by the Laboratory, the remainder being purchased with the funds awarded for this purpose by the Government Grant Committee of the Royal Society.

All experiments recorded in the present communication refer to the 500 c.c. spherical enclosure.

The Pressure Gauges.—Two distinct gauges are used. The first measures the maximum pressure attained and in principle is similar to Bunsen's original apparatus. A piston lifts or does not lift according to whether the explosive pressure does or does not rise above the pressure corresponding to the weight with which the piston is held down. In the present case, however, to diminish the inertia of the system, the weights are replaced by a gaseous pressure acting on the opposite end of the piston. The areas of the two piston heads being in the ratio of 50 to 1, an explosive pressure of 500 atmospheres is exactly balanced by a gaseous pressure of 10 atmospheres acting on the other side of this equilibrium valve. To render the action of the apparatus as rapid as possible, the travel of the piston is limited by means of a micrometer screw to two or three thousandths of an inch. The piston, on coming in contact with this micrometer screw, closes an electric circuit communicating with an indicator. As an example of the method a series of observations are given in the table.

TABLE.

No. of Experiment	Initial Pressure in Atmospheres	Explosive Pressure in Atmospheres		Ratio of Explosive Pressure to Initial Pressure		Total Residue per cent.	Residue of H or O per cent.	
8	42·05	Below	427·4	Below	10·17	1·54	0·84	O
11	42·01	„	424·4	„	10·10	1·395	0·258	H
12	42·14	„	423·6	„	10·05	2·098	—	H
10	41·88	Above	421·4	Above	10·06	1·602	0·656	O
9	42·02	„	422·6	„	10·05	1·48	0·90	O
6	42·53	„	414·1	„	9·74	2·35	1·50	O

The second measuring apparatus is in principle the same as the well-known steam-engine indicator. The ordinary spring is, however, replaced by a brass cylinder. The only motion which the piston can make is therefore that allowed by the elastic compression of the metal. The time period of the system has not yet been measured, but from the diagrams recorded, it is evidently below one five-thousandth of a second. The maximum motion of the piston is less than one thousandth of an inch. The motion of the piston, magnified to the desired extent by a special device, is photographed on the cylinder of a rapidly revolving chronograph.

The scale of time on the indicator card thus obtained can be varied from one hundredth of a second per millimetre to one five-thousandth of a second per millimetre.

The Results obtained.—The records show a rapid initial rise of pressure, the rate decreasing as the temperature of dissociation is approached. It is intended to obtain a series of these indicator diagrams for initial pressures varying between 10 and 200 atmospheres.

Many years ago Bunsen found that a mixture of oxygen and hydrogen fired at atmospheric pressure gave an explosive pressure of 9·5 atmospheres. The present experiments show that this ratio is still substantially correct up to initial pressures of 42 atmospheres, the ratio actually given by Table I. being 10·06.

The ratio diminishes but slowly as the proportion of explosive gas to non-explosive gas decreases. A mixture of H_2O and oxygen, containing but 49 per cent. of explosive gas, still gives an explosive pressure of 319 atmospheres when fired at an initial pressure of 42 atmospheres, the ratio being therefore 7·6.

Under the same conditions a mixture containing 28·7 per cent. of explosive gas gives a ratio of 6·16. Finally, a mixture containing only 12 per cent. of H_2O is not explosive.

As will be seen, even the few results that have as yet been obtained raise many interesting questions, but with the limited data which as yet are available it would be unwise to attempt any general discussion of the results.

It is hoped, however, that before long a series of experiments will be completed giving the necessary data for all mixtures of oxygen and hydrogen at all initial pressures between one atmosphere and 200 atmospheres.

On the Relations of Radiation to Temperature. *By* Dr. J. Larmor, *F.R.S.*

The key to this subject is the principle, arrived at independently by Balfour Stewart and Kirchhoff about the year 1857, that the constitution and intensity of the steady radiation in an enclosure is determined by the temperature of the surrounding bodies, and involves no other element. It was pointed out by Stewart[1] that if the enclosure contains a radiating and absorbing body which is put in motion, the temperature being uniform throughout, then the constitutions of the radiation in front of it and behind it will differ on account of the Doppler effect, so that there will be a chance of gaining mechanical work in the restoration of a uniform state. There must thus be some kind of thermodynamic compensation, which might arise from æthereal friction, or from work required to produce the motion of the body against pressure excited by the surrounding radiation. The hypothesis of friction is now out of court in ultimate molecular physics; while the thermodynamic bearing of a pressure produced by radiation has been developed by Bartoli and Boltzmann (1884), and that of the Doppler effect by Wien (1893).

Application of the Doppler Principle.—The procedure of Wien amounts to isolating a region of radiation within a perfectly reflecting enclosure, and estimating the average shortening of the constituent wave-lengths produced by a very slow shrinkage of its volume. The argument is, however, much simplified if the enclosure is taken to be spherical and to remain so; for it may then be easily shown that each individual undulation is shortened in the same ratio as is the radius of the enclosure, so that the undulatory content remains similar to itself, with uniformly shortened wave-lengths, whether it is uniformly distributed as regards direction or not, and whatever its constitution may be. But if there is a very small piece of a material radiator in the enclosure, the radiation initially inside will have been reduced by its radiating and absorbing action to that corresponding to its temperature. In that case the shrinkage must retain it always, at each stage of its transformation, in the constitution corresponding to some temperature. Otherwise differences of temperature would be effectively established between the various constituents of the radiation in the enclosure; these could be permanent in the absence of material bodies; but if the latter are present this would involve degradation of their energy, for which there is here no room, because, on the principles of Stewart and Kirchhoff, the state corresponding to given energy and volume and temperature is determinate. Thus we infer that if the wave-lengths of the steady radiation corresponding to any one temperature are all altered in the same ratio, we obtain a distribution which corresponds to some other temperature in every respect except absolute intensities.

Direct Transformation of Mechanical Energy into Radiation.[2]—There is one point, however, that rewards examination. When undulations of any kind are reflected from an advancing wall, there is slightly more energy in the reflected

[1] *Brit. Assoc. Report*, 1871; *cf.* also *Encycl. Brit.*, art. 'Radiation' (1886), by Tait.

[2] The present form of this argument arose out of some remarks contributed by Professor FitzGerald, and by Mr. Alfred Walker of Bradford, to the discussion on this paper. Mr. Walker points out that by reflecting the radiation from a hot body, situated at the centre of a wheel, by a ring of oblique vanes around its circumference, and then reversing its path by direct reflexion from a ring of fixed vanes outside the wheel, so as to return it into the source, its pressure may be (theoretically) utilised to drive the wheel, and in time to get up a high speed if there is no load: the thermodynamic compensation in this very interesting arrangement lies in the lowering of the temperature of the part of the incident radiation that is not thus utilised.

beam than there was in the incident beam, although its length is shorter on account of the Doppler effect. This requires that the undulations must oppose a resistance to the advancing wall, and that the mechanical work required to push on the wall is directly transformed into undulatory energy. In fact, let us consider the mechanism of the reflexion. Suppose the displacement in a directly incident wave-train, with velocity of propagation c, to be $\xi = a \cos (mx - mct)$; that in the reflected train will be $\xi' = a' \cos (m'x + m'ct)$, where a', m' are determined by the condition that the total displacement is annulled at the advancing reflector, because no disturbance penetrates beyond it; therefore when $x = vt$, where v is its velocity, $\xi + \xi' = o$. Thus we must have $a' = -a$, and $m' = m\dfrac{c-v}{c+v}$, in agreement with the usual statement of the Doppler effect when v is small compared with c. Observe, in fact, that the direct and reflected wave-trains have a system of nodes which travel with velocity v, and that the moving reflector coincides with one of them. Now the velocities $d\xi/dt$ and $d\xi'/dt$ in these two trains are not equal. Their mean squares, on which the kinetic energy per unit length depends, are as m^2 to m'^2. The potential energies per unit length depend on the means of $(d\xi/dx)^2$ and $(d\xi'/dx)^2$, and are of course in the same ratio. Thus the energies per unit length in the direct and reflected trains are as m^2 to m'^2, while the lengths of the trains are as m' to m; hence their total energies are as m to m'; in other words the reflected train has received an accretion of energy equal to $1 - m'/m$ of the incident energy, which can only have come from mechanical work spent in pushing on the reflector with its velocity v. The opposing pressure is thus in numerical magnitude the fraction $\left(1 - \dfrac{m'}{m}\right)\dfrac{c}{v}$ of the density of the incident energy, which works out to be $\dfrac{c^2 - v^2}{c^2 + v^2}$ of the intensity of the total undulatory energy, direct and reflected, that is in front of the reflector.

When v is small compared with c, this agrees with Maxwell's law for the pressure of radiation. This case is also theoretically interesting, because in the application to æther-waves ξ is the displacement of the æther elements whose velocity $d\xi/dt$ represents the magnetic force; so that here we have an actual case in which this vector ξ, hitherto introduced only in the theoretical dynamics of electron-theory, is essential to a bare statement of the facts. Another remark here arises. It has been held that a beam of light is an irreversible agent, because the radiant pressure at the front of the beam has nothing to work against, and its work is therefore degraded. But suppose it had a reflector moving with its own velocity c to work against; our result shows that the pressure vanishes and no work is done. Thus that objection to the thermodynamic treatment of a single ray is not well founded.

This generalisation of the theory of radiant pressure to all kinds of undulatory motion is based on the conservation of the energy. It remains to consider the mechanical origin of the pressure. In the special case of an unlimited stretched cord carrying transverse waves the advancing reflector may be a lamina, through a small hole in which the cord passes without friction: the cord is straight on one side of the lamina, and inclined on the other side on account of the vibration; and it is easily shown that the resultant of the tensions on the two sides provides a force acting on the lamina which, when averaged, agrees with the general formula. In the case of an extended medium with advancing transverse waves, which are reflected directly, the origin of the pressure is not so obvious, because there is not an obvious mechanism for a reflector which would sweep the waves in front of it as it advances. In the æthereal case we can, however, on the basis of electron-theory, imagine a constitution for a reflector which will turn back the radiation on the same principle as a metallic mirror totally reflects Hertzian waves, and thus obtain an idea of how the force acts.

The case of direct incidence has here been treated for simplicity; that of oblique incidence easily follows; the expression for the pressure is reduced in the ratio of the square of the cosine of the angle of incidence. If we average up, after Boltzmann, for the natural radiation in an enclosure, which is incident equally at

all angles, we find that the pressure exerted is one third of the total density of radiant energy.

Adiabatics of an enclosed Mass of Radiation, and resulting General Laws.—Now consider an enclosure of volume V containing radiant energy travelling indifferently in all directions, and of total density E; and let its volume be shrunk by δV. This requires mechanical work $\frac{1}{3} E\delta V$, which is changed into radiant energy: thus

$$EV + \tfrac{1}{3} E\delta V = (E - \delta E)(V - \delta V),$$

where $E - \delta E$ is the new density at volume $V - \delta V$. This gives $\frac{4}{3} E\delta V = V\delta E$, or $E \propto V^{-\frac{4}{3}}$.

As already explained, if the original state has the constitution as regards wave-lengths corresponding to a temperature T, the new state must correspond to some other temperature $T - \delta T$. Thus we can gain work by absorbing the radiation into the working substance of a thermal engine at the one temperature, and extracting it at the other; as the process is reversible, we have by Carnot's principle

$$\tfrac{1}{3} E\delta V/EV = -\delta T/T,$$

so that $T \propto V^{-\frac{1}{3}}$.

Thus $E \propto T^4$, which is Stefan's law for the relation of the aggregate natural radiation to the temperature.

Moreover the Doppler principle has shown us that in the uniform shrinkage of a spherical enclosure the wave-lengths diminish as the linear dimensions, and therefore as $V^{\frac{1}{3}}$, or inversely as T by the above result. Thus in the radiations at different temperatures, if the scale of wave-length is reduced inversely as the temperature the curves of constitution of the radiation become homologous, *i.e.*, their ordinates are all in the same ratio. This is Wien's law.

These relations show that the energy of the radiation corresponding to the temperature T, which lies between wave-lengths λ and $\lambda + \delta\lambda$, is of the form $\lambda^{-5} f(\lambda T)\, \delta\lambda$. The investigation, theoretical (Wien, Planck, Rayleigh, etc.) and experimental (Lummer and Pringsheim, Paschen, etc.) of the form of this function f is perhaps the most fundamental and interesting problem now outstanding in the general theory of the relation of radiation to temperature. The theoretical relations on which this expression is founded have been shown to be in agreement with fact; and it appears that the form $c_1 e^{-c_2/\lambda T}$ fairly represents $f(\lambda T)$ over a wide range of temperature. These relations have been derived, as usual, from a dynamical discussion of the aggregate intensity of radiation belonging to the temperature; it may be shown that the same results, but nothing in addition, will be gained by applying the same principles to each constituent of range $\delta\lambda$ by itself, assigning to each its own temperature.

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6. *On the Infra-red of the Solar Spectrum.* *By* Dr. S. P. Langley, *F.R.S.*

DEPARTMENT OF ASTRONOMY.

Chairman: Dr. A. A. Common, F.R.S., F.R.A.S.

FRIDAY, SEPTEMBER 7.

The Chairman delivered the following Address:—

It has been decided to form a Department of Astronomy under Section A, and I have been requested to give an Address on the occasion. In looking up the records of the British Association to see what position Astronomy has occupied, I was delighted to find, in the very first volume, 'A Report on the Progress of Astronomy during the Present Century,' made by the late Sir George Airy, so

many years our Astronomer Royal, and at that time Plumian Professor of Astronomy at Cambridge. This report, made at the second meeting of the Association, describes, in a most interesting manner, the progress that was made during the first third of the century, and we can gather from it the state of astronomical matters at that time. The thought naturally occurred to me to give a report, on the same lines, to the end of this century, but a little consideration showed that it was impossible in the limited time at my disposal to give more than a bare outline of the progress made.

At the time this report was written we may say, in a general way, that the astronomy of that day concerned itself with the position of the heavenly bodies only, and, except for the greater precision of observation resulting from better instruments and the larger number of observatories at work, this, the gravitational side of astronomy, remains much as it was in Airy's time.

What has been aptly called the New or Physical Astronomy did not then exist. I propose to briefly compare the state of things then existing with the present state of the science, without dealing very particularly with the various causes operating to produce the change; to allude briefly to the new astronomy; and to speak rather fully about astronomical instruments generally, and of the lines on which it is most probable future developments will be made.

In this report[1] we find that at the beginning of the century the Greenwich Observatory was the only one in which observations were made on a regular system. The thirty-six stars selected by Dr. Maskelyne, and the sun and moon, were observed on the meridian with great regularity, the planets very rarely and only at particular parts of their orbits; small stars, or stars not included in the thirty-six, were seldom observed.

This state of affairs was no doubt greatly improved at the epoch of the report, but it contrasts strongly with the present work at Greenwich, where 5,000 stars were observed in 1899, in addition to the astrographic, spectroscopic, magnetic, meteorological, and other work.

Many observatories, of great importance since, were about that time founded, those at Cambridge, Cape of Good Hope, and Paramatta having just been started. A list is given of the public observatories then existing, with the remark that the author is 'unaware that there is any public observatory in America, though there are,' he says, 'some able observers.'

The progress made since then is truly remarkable. The first public observatory in America was founded about the middle of the century, and now public and private observatories number about 150, while the instrumental equipment is in many cases superior to that of any other country. The prophetic opinion of Airy about American observers has been fully borne out. The discovery of two satellites to Mars by Hall in 1877, of a fifth satellite to Jupiter by Barnard in 1892, and the discovery of Hyperion by Bond, simultaneously with Lassell, in 1848, are notable achievements.

The enormous amount of work turned out by the Harvard Observatory and its branches in South America, all the photographic and spectroscopic work carried out by many different astronomers, and the new lines of research initiated show an amount of enthusiasm not excelled by any other country. A greater portion of the astronomical work in America has been on the lines of the new astronomy, but the old astronomy has not been at all neglected. In this branch pace has been kept with other countries.

From this report we gather that the mural quadrant at most of the observatories was about to be replaced by the divided circle. Troughton had perfected a method of dividing circles, which, as the author says, 'may be considered as the greatest improvement ever made in the art of instrument making.'

Two refractors of 11 and 12 inches aperture had just been imported into this country; clockwork for driving had been applied to the Dorpat and Paris equatorials, but the author had not seen either in a state of action.

The method of mounting instruments adopted by the Germans was rather

[1] *Brit. Assoc. Report*, 1831–32, p. 125.

severely criticised by the author, the general principle of their mounting being 'telescopes are always supported at the middle, not at the ends.'

'Every part is, if possible, supported by counterpoises.'

'To these principles everything is sacrificed. For instance, in an equatorial the polar axis is to be supported in the middle by a counterpoise. This not only makes the instrument weak (as the axis must be single), but also introduces some inconvenience into the use of it. The telescope is on one side of the axis; on the other side is a counterpoise. Each end of the telescope has a counterpoise. A telescope thus mounted must, I should think, be very liable to tremor. If a person who is no mechanic and who has not used one of these instruments may presume to give an opinion, I should say that the Germans have made no improvement in instruments except in the excellence of the workmanship.'

I have no doubt that this question had often occupied Airy's mind, for in the Northumberland Equatorial Telescope which he designed shortly after for Cambridge he adopted what has been called the English form of mounting, where the telescope is supported by a pivot at each side, and a long polar axis is supported at each end. This telescope is in working order at the present time at Cambridge.

When he became Astronomer Royal he used the same design for what was for many years the great equatorial at Greenwich, though the wooden uprights forming the polar axis were in the Greenwich telescope replaced by iron. It says much for the excellence of the design and workmanship of this mounting, designed as it was for an object glass of about 13 inches diameter, when we find the present Astronomer Royal, Mr. Christie, has used it to carry a telescope of 28 inches aperture, and that it does this perfectly.

Notwithstanding the greater steadiness of the English form of mounting, the German form has been adopted generally for the mounting of the large refractors recently made.

There is much interesting matter in this report of an historical character.

As I have already said, the new astronomy, as we know it, did not exist, but in a report[1] on optics, in the same volume, by Sir David Brewster, we find that spectrum analysis was then occupying attention, and the last paragraph of this report is well worth quoting: 'But whatever hypothesis be destined to embrace and explain this class of phenomena, the fact which I have mentioned opens an extensive field of inquiry. By the aid of the gaseous absorbent we may study with the minutest accuracy the action of the elements of material bodies in all their variety of combinations, upon definite and easily recognised rays of light, and we may discover curious analogies between their affinities and those which produce the fixed lines in the spectra of the stars. The apparatus, however, which is requisite to carry on such inquiries with success cannot be procured by individuals, and cannot even be used in ordinary apartments. Lenses of large diameter, accurate heliostats, and telescopes of large aperture are absolutely necessary for this purpose; but with such auxiliaries it would be easy to construct optical combinations, by which the defective rays in the spectra of all the fixed stars down to the *tenth* magnitude might be observed, and by which we might study the effects of the very combustion which lights up the suns of other systems.'

Brewster's words are almost prophetic, and it would almost appear as if he unknowingly held the key to the elucidation of the spectrum lines, for it was not until 1859 that Kirchhoff's discovery of the true origin of the dark lines was made.

Fraunhofer was the first to observe the spectra of the planets and the stars, and to notice the different types of stellar spectra. In 1817 he recorded the spectrum of Venus and Sirius, and later, in 1823, he described the spectrum of Mars; also Castor, Pollux, Capella, Betelgeux, and Procyon.

Fraunhofer, Lamont, Donati, Brewster, Stokes, Gladstone, and others carried on their researches at a time when the principles of spectrum analysis were unknown, but immediately upon Kirchhoff's discovery great interest was awakened.

With spectrum analysis thus established, aided as it was later by the greater development of photography, the new astronomy was firmly established.

[1] *Brit. Assoc. Rep.*, 1831–32, p. 308

The memorable results arrived at by Kirchhoff were no sooner published than they were accepted without dissent. The works of Stokes, Foucault, and Ångström at that period were all suggestive of the truth, but do not mark an epoch of discovery.

Astronomical spectroscopy divided itself naturally into two main branches, the one of the sun, the other of the stars, each having its many offshoots. I shall just mention a few points relating to each. The dark lines in the solar spectrum had already been mapped by Fraunhofer, and now it only needed better instruments and the application of laboratory spectra with Kirchhoff's principle to advance this work still further.

Fraunhofer had already pointed out the way in using gratings, and these were further improved by Nobert and Rutherfurd.

Kirchhoff's Map of the Solar Spectrum, published in 1861–62, was the most complete up to that time; but the scale of reference adopted by him was an arbitrary one, so that it was not long before this was improved upon. Ångström published in 1868 his map of the 'Normal Solar Spectrum,' adopting the natural scale of wave-lengths for reference, and this remained in use until quite recent times.

The increased accuracy in the ruling of gratings by Rutherfurd materially improved the efficiency of the solar spectroscope, but it was not until Professor Rowland's invention of the concave grating that this work gained any decisive impetus. The maps (first published in 1885) and tables (published in the years 1896–98) of the lines of the solar spectrum are now almost universally accepted and adopted as a standard of reference. These tables alone record about 10,000 lines in the spectrum of the sun, which is in marked contrast to the number 7 recorded by Wollaston at the beginning of the century (1802). Good work in the production of maps has also been done in this country by Higgs.

Michelson has also recently invented a new form of spectroscope called the 'Echelon,'[1] in which a grating with a relatively small number of lines is employed, the dispersion necessary for modern work being obtained by using a high order (say the hundredth) into which most of the light has been concentrated.

Besides lines recorded in the visual and ultra-violet portions of the solar spectrum, maps have been made of the lines in the infra-red, the most important being that of Langley's, published in 1894, prepared by the use of his 'bolometer.' Good work had, however, been done in this direction previously by Becquerel, Lamansky, and Abney; the last, indeed, succeeded even in photographing a part of it.

The recording of the Fraunhofer lines in the solar spectrum is not all, however. The application of the spectroscope to the sun has several epoch-marking events attached to it, notably those of proving the solar character of the prominences and corona, the rendering visible of the prominences without the aid of an eclipse by the discovery of Lockyer and Janssen in 1868, the photography of the prominences both round the limb and those projected on the solar disc by the invention of the spectro-heliograph by Hale and Deslandres in 1890.

Success has not yet favoured the many attempts to photograph the corona without an eclipse by spectroscopic means; but even now this problem is being attacked by Deslandres with the employment of the calorific rays.

Spectroscopic work on the sun has led to the discovery of many hundreds of dark lines, the counterparts of which it has not yet been possible to produce on the earth.

But besides those unknown substances which reveal their presence by dark lines, there were two others discovered, which showed themselves only by bright lines, the one in the chromosphere, to which the name of Helium was given, and the other in the corona, to which the name of Coronium was applied.

The former was, however, identified terrestrially by Ramsay in 1895, though the latter is still undetermined. The revision of its wave-length, brought about by the observations of the eclipse of 1898, may, however, result in this element being transferred from the unknown to the known in the near future.

[1] *Ast. Phys. Journ.*, vol. viii. 1898, p. 37.

The study of stellar spectra was taken up by Huggins, Rutherfurd, and Secchi. Rutherfurd[1] published in 1862 his results upon a number of stars, and suggested a rough classification of the white and yellow stars; but Secchi deserves the high credit of introducing the first systematic differentiation of the stars according to their spectra, he having begun a spectroscopic survey of the heavens for the purposes of classification,[2] whilst Huggins devoted himself to the thorough analysis of the spectra of a few stars.

The introduction of photography marks another epoch in the study of stellar spectra. Sir William Huggins applied photography as early as 1863,[3] and secured an impression of the spectrum of Sirius, but nearly another decade elapsed before Professor H. Draper[4] took a photograph of the spectrum of Vega in 1872, which was the first to record any lines. With the introduction of dry plates this branch of the new astronomy received another impetus, and the catalogues of stellar spectra have now become numerous. Among them may be mentioned those of Harvard College, Potsdam, Lockyer, McClean, and Huggins. The Draper Catalogue[5] of the Harvard College, which is a spectroscopic Durchmusterung, alone contains the spectra of 10,351 stars down to the 7–8 magnitudes, and this has further been extended by work at Arequipa, whilst Vogel and Müller of Potsdam[6] made a spectroscopic survey of the stars down to the 7·5 magnitude between $-1°$ and $+20°$ declination. This has again been supplemented by Scheiner[7] ('Untersuchungen über die Spectra der helleren Sterne'), and by Vogel and Wilsing[8] ('Untersuchungen über die Spectra von 528 Sternen'). Lockyer[9] in 1892 published a series of large-scale photographs of the brighter stars, and more recently McClean[10] has completed a spectroscopic survey of the stars of both hemispheres down to the $3\frac{1}{2}$ magnitude. For the study and investigation of special types of stars, the researches of Dunér on the red stars made at Upsala, and those of Keeler and Campbell on the bright line stars made at the Lick Observatory, deserve mention. For the study of stellar spectra the use of prisms in slit or objective prism spectroscopes has predominated, though more recently the use of specially ruled gratings has been attended by some degree of success at the Yerkes Observatory.

Several new stars have also been discovered by their spectra by Pickering in his routine work of charting the spectra of the stars in different portions of the sky. The photographic plate containing their peculiar spectra was, however, not examined in many cases until the star had died down again.

Spectrum analysis also opened up another field of inquiry, viz., that of the motion of the stars in the line of sight, based on the process of reasoning due to Doppler, and accordingly named Doppler's Principle.[11]

The observatories of Greenwich and Potsdam were among the first to apply this to the stars, and more recently Campbell at Lick, Newall at Cambridge, and Belopolsky at Pulkowa have made use of the same principle with enormous success.

It was also discovered that there are certain classes of stars having a large component velocity in the line of sight, which changes its direction from time to time, and in many such cases orbital motion has been proven, as in the case of Algol.

Another class of binary stars has also been discovered spectroscopically and explained by Doppler's principle. I refer to the stars known as spectroscopic binaries, in which the spectrum lines of one luminous source reciprocate over those

[1] *Am. Journ.*, vol. xxxv. 1862, p. 77.
[2] *Comptes Rendus*, t. lvii. 1853.
[3] *Phil. Trans.*, 1864, p. 428.
[4] *Am. Journ. of Soc. and Arts.*, vol. xviii. 1879, p. 421.
[5] *Annals Harvard Coll.*, vol. xxvii. 1890.
[6] *Astro-Phys. Obs. zu Potsdam*, vol. iii. 1882–83.
[7] *Ibid.*, vol. vii. 1895.
[8] *Ibid.*, vol. xii. 1899.
[9] *Phil. Trans.*, vol. clxxxiv. A, 1893.
[10] *Phil. Trans.*, vol. cxci. A, 1898.
[11] 'Ueber das farbige Licht der Doppelsterne,' . . . *Abhandl. der K. Böhmischen Ges. d. Wiss.* V. Folge, 2. Bd. 1843.

from the other source of light, according as one is moving towards or away from the earth. This displacement of the spectrum lines led to the discovery of the duplicity of β Aurigæ, and ζ Ursæ Majoris by Pickering.[1]

Several other such stars have now been detected, notably β Lyræ, and lastly Capella, discovered independently by Campbell[2] at Lick, and Newall[3] at Cambridge.

The progress of the new astronomy is so closely bound up with that of photography that I shall briefly call to mind some of the many achievements in which photography has aided the astronomer.

Daguerre's invention in 1839 was almost immediately tried with the sun and moon, J. W. Draper and the two Bonds in America, Warren de la Rue in this country, and Foucault and Fizeau in France, being among the pioneers of celestial photography; but no real progress seems to have been made until after the introduction of the collodion process. Sir John Herschel in 1847 suggested the daily self-registration of the sun-spots to supersede drawings; and in 1857 the De la Rue photo-heliograph was installed at Kew. From 1858–72 a daily record was maintained by the Kew photo-heliograph, when the work was discontinued. Since 1873 the Kew series has been continued at Greenwich, which is supplemented by pictures from Dehra Dûn in India and from Mauritius. The standard size of the sun's disc on these photographs has now been for many years 8 inches, though for some time a 12-inch series was kept up.

The first recorded endeavour to employ photography for eclipse work dates back to 1851, when Berowsky obtained a daguerreotype of the solar prominences during the total eclipse. From that date nearly every total eclipse of the sun has been studied by the aid of photography.

In 1860 the first regularly planned attack on the problem by means of photography was made, when De la Rue and Secchi successfully photographed the prominences and traces of the corona, but it was not until 1869 that Professor Stephen Alexander obtained the first good photograph of the corona.

In recent years, from 1893 up to the total eclipse which occurred last May, photography has been employed to secure large-scale pictures of the corona. These were inaugurated in 1893 by Professor Schaeberle, who secured a 4-inch picture of the eclipsed sun in Chili: these have been exceeded by Professor Langley, who obtained a 15-inch picture of the corona in North Carolina during the eclipse of May 1900.

Photography also supplied the key to the question of the prominences and corona being solar appendages, for pictures of the eclipse sun taken in Spain in 1860 terminated this dispute with regard to the prominences, and finally to the corona in 1871.

In 1875, in addition to photographing the corona, attempts were made to photograph its spectrum, and at every eclipse since then the sensitised plate has been used to record both the spectrum of the chromosphere and the corona. The spectrum of the lower layers of the chromosphere was first successfully photographed during the total eclipse of 1896 in Nova Zembla by Mr. Shackleton, though seen by Young as early as 1870, and a new value was given to the wave-length of the coronal line (wrongly mapped by Young in 1869) from photographs taken by Mr. Fowler during the eclipse of 1898 (India).

Lunar photography has occupied the attention of various physicists from time to time, and when Daguerre's process was first enunciated, Arago proposed that the lunar surface should be studied by means of the photographically produced images. In 1840 Dr. Draper succeeded in impressing a daguerreotype plate with a lunar image by the aid of a 5-inch refractor. The earliest lunar photographs, however, shown in England were due to Professor Bond, of the United States. These he exhibited at the Great Exhibition in 1851. Dancer, the optician, of Manchester, was perhaps the first Englishman who secured lunar images, but they were of small size.[4]

Another skilful observer was Crookes, who obtained images of 2 inches

[1] *Am. Jour.* (3), 39, p. 46 (1890).
[2] *Astro-Phys. Jour.*, vol. x. p. 177.
[3] *Monthly Notices*, vol. lx. p. 2 (1899).
[4] Abney, *Photography*.

diameter with an 8-inch refractor of the Liverpool Observatory. In 1852 De la Rue began experimenting in lunar photography. He employed a reflector of some 10 feet focal length and about 13 inches diameter. A very complete account of his methods is given in a paper read before the British Association. Mr. Rutherfurd at a later date having tried an 11½-inch refractor, and also a 13-inch reflector, finally constructed a photographic refracting telescope, and produced some of the finest pictures of the moon that were ever taken until recent years. Also Henry Draper's picture of the moon taken September 3, 1863, remained unsurpassed for a quarter of a century.

Admirable photographs of the lunar surface have been published in recent years by the Lick Observatory and others. I myself devoted considerable attention to this subject at one time. Photographs surpassing anything before attempted were published in 1896–99 by MM. Loëwy and Puiseux, taken with the Equatorial Coudé of the Paris Observatory.

Star prints were first secured at Harvard College, under the direction of W. C. Bond, in 1850; and his son, G. P. Bond, made in 1857 a most promising start with double-star measurements on sensitive plates, his subject being the well-known pair in the tail of the Great Bear. The competence of the photographic method to meet the stringent requirements of exact astronomy was still more decisively shown in 1866 by Dr. Gould's determination from his plates of nearly fifty stars in the Pleiades. Their comparison with Bessel's places for the same objects proved that the lapse of a score of years had made no difference in the configuration of that immemorial cluster; and Professor Jacoby's recent measures of Rutherfurd's photographs taken in 1872 and 1874 enforce the same conclusion.

The above facts are so forcible that no wonder that at the Astrophotographic Congress held in Paris in 1887 it was decided to make a photographic survey of the heavens, and now eighteen photographic telescopes of 13 inches aperture are in operation in various parts of world, for the purpose of preparing the international astrographic chart, and it was hoped that the catalogue plates would be completed by 1900.

Photography has been applied so assiduously to the discovery of minor planets that something like 450 are now known, the most noteworthy, perhaps, as regards utility being the discovery of Eros (433) in 1898 by Herr Witt at the Observatory Urania, near Berlin.

With regard to the application of photography to recording the form of various nebulæ, it is interesting to quote a passage from Dick's 'Practical Astronomer,' published in 1845, as opposed to Herschel's opinion that the photography of a nebula would never be impossible.

'It might, perhaps, be considered as beyond the bounds of probability to expect that even the distant nebulæ might thus be fixed, and a delineation of their objects produced, which shall be capable of being magnified by microscopes. But we ought to consider that the art is only in its infancy, and that plates of a more delicate nature than those hitherto used may yet be prepared, and that other properties of light may yet be discovered, which shall facilitate such designs. For we ought now to set no boundaries to the discoveries of science, and to the practical applications of scientific discovery, which genius and art may accomplish.'

It was not, however, until 1880 that Draper first photographed the Orion Nebula, and later by three years I succeeded in doing the same thing with an exposure of only thirty-seven minutes. In December 1885 the brothers Henry by the aid of photography found that the Pleiades were involved in a nebula, part of which, however, had been seen by myself [1] with my 3-foot reflector in February 1880, and later, February 1886, it was also partly discerned at Pulkowa with the 30-inch refractor then newly erected.

Still more nebulosity was shown by Dr. Roberts's photographs,[2] taken with his 20-inch reflector in October and December 1886, when the whole western side of the group was shown to be involved in a vast nebula, whilst a later photograph taken by MM. Henry early in 1888 showed that practically the whole of the group was a shoal of nebulous matter.

[1] *Monthly Notices*, vol. xl. p. 376.

[2] *Monthly Notices*, vol. xlvii. p. 24.

In 1881 Draper and Janssen recorded the comet of that year by photography. Huggins[1] succeeded in photographing a part of the spectrum of the same object, (Tebbutt's Comet 1881, II.) on June 24, and the Fraunhofer lines were amongst the photographic impressions, thus demonstrating that at least a part of the continuous spectrum is due to reflected sunlight. He also secured a similar result from Comet Wells.[2]

I propose to consider the question of the telescope on the following lines: (1) The refractor and reflector from their inception to their present state. (2) The various modifications and improvements that have been made in mounting these instruments, and (3) the instrument that has been lately introduced by a combination of the two, refractor and reflector, a striking example of which exists now at the Paris Exhibition.

At a meeting of the British Association held nearly half a century ago (1852) (Belfast) Sir David Brewster showed a plate of rock crystal worked in the form of a lens which had been recently found in Nineveh. Sir David Brewster asserted that this lens had been destined for optical purposes, and that it never was a dress ornament.

That the ancients were acquainted with the powers of a magnifying lens may be inferred from the delicacy and minuteness of the incised work on their seals and intaglios, which could only have been done by an eye aided by a lens of some sort.

There is, however, no direct evidence that the ancients were really acquainted with the refracting telescope, though Aristotle speaks of the tubes through which the ancients observed distant objects, and compares their effect to that of a well from the bottom of which the stars may be seen in daylight.[3] As an historical fact without any equivocations, however, there is no serious doubt that the telescope was invented in Holland.

The honour of being the originator has been claimed for three men, each of whom has had his partisans. Their names are Metius, Lippershey, and Janssen.

Galileo himself says that it was through hearing that some one in France or Holland had made an instrument which magnified distant objects that he was led to inquire how such a result could be obtained.

The first publisher of a result or discovery, supposing such discovery to be honestly his own, ranks as the first inventor, and there is little doubt that Galileo was the first to show the world how to make a telescope.[4] His first telescope was made whilst on a visit to Venice, and he there exhibited a telescope *magnifying three times*: this was in May 1609. Later telescopes which emanated from the hands of Galileo magnified successively four, seven, and thirty times. This latter number he never exceeded.

Greater magnifying power was not attained until Kepler explained the theory and some of the advantages of a telescope made of two convex lenses in his *Catoptrics* (1611). The first person to actually apply this to the telescope was Father Scheiner, who describes it in his *Rosa Ursina* (1630), and Wm. Gascoigne was the first to appreciate practically the chief advantages by his invention of the micrometer and application of telescopic sights to instruments of precision.

It was, however, not until about the middle of the seventeenth century that Kepler's telescope came to be nearly universal, and then chiefly because its field of view exceeded that of the Galilean.

The first powerful telescopes were made by Huyghens, and with one of these he discovered Titan (Saturn's brightest satellite): his telescopes magnified from forty-eight to ninety-two times, were about $2\frac{1}{3}$ inches aperture, with focal lengths ranging from 12 to 23 feet. By the aid of these he gave the first explanation of Saturn's ring, which he published in 1659.

Huyghens also states that he made object-glasses of 170 feet and 210 feet focal length; also one 300 feet long, but which magnified only 600 times; he also presented one of 123 feet to the Royal Society of London.

[1] *Proc. Roy. Soc.*, vol. xxxii. No. 213.
[2] *Rep. Brit. Assoc.*, 1882, p. 442.
[3] *De Gen. Animalium*, lib. v.
[4] Newcomb's *Astronomy*, p. 108.

Auzout states that the best telescopes of Campani at Rome magnified 150 times, and were of 17 feet focal length. He himself is said to have made telescopes of from 300 to 600 feet focus, but it is improbable that they were ever put to practical use. Cassini discovered Saturn's fifth satellite (Rhea) in 1672, with a telescope made by Campani, magnifying about 150 times, whilst later, in 1684, he added the third and fourth satellites of the same planet to the list of his discoveries.

Although these telescopes were unwieldy, Bradley, with his usual persistency, actually determined the diameter of Venus in 1722 with a telescope of 212 feet focal length.

With such cumbersome instruments many devices were invented of pointing these *aërial telescopes*, as they were termed, to various parts of the sky. Huyghens contrived some ingenious arrangements for this purpose, and also for adjusting and centreing the eyepiece, the object-glass and eyepiece being connected by a long braced rod.

It was not, however, until Dollond's invention of the achromatic object-glass in 1757–58 that the refracting telescope was materially improved, and even then the difficulty of obtaining large blocks of glass free from striæ limited the telescope as regards aperture, for even at the date of Airy's report we have seen that 12 inches was about the maximum aperture for an object-glass.

The work of improving glass dates back to 1784, when Guinand began experimenting with the manufacture of optical flint glass.

He conveyed his secrets to the firm of Fraunhofer and Utzschneider, whom he joined in 1805, and during the period he was there they made the 9·6 inches object-glass for the Dorpat telescope.

Merz and Mädler, the successors of Fraunhofer, carried out successfully the methods handed down to them by Guinand and Fraunhofer.

Guinand communicated his secrets to his family before his death in 1823, and they entered into partnership with Bontemps. The latter afterwards joined the firm of Chance Bros., of Birmingham, and so some of Guinand's work came to England.

At the present day MM. Feil, of Paris, who are direct descendants of Guinand and Messrs. Chance Bros., of Birmingham, are the best known manufacturers of large discs of optical glass.

It is related in history that Ptolemy Euergetes had caused to be erected on a lighthouse at Alexandria a piece of apparatus for discovering vessels a long way off; it has also been maintained that the instrument cited was a concave reflecting mirror, and it is possible to observe with the naked eye images formed by a concave mirror, and that such images are very bright.

Also the Romans were well acquainted with the concentrating power of concave mirrors, using them as burning mirrors, as they were called. The first application of an eye lens to the image formed by reflection from a concave mirror appears to have been made by Father Zucchi, an Italian Jesuit. His work was published in 1652, though it appears he employed such an instrument as early as 1616. The priority, however, of describing, if not making, a practical reflecting telescope belongs to Gregory, who, in his 'Optica Promota,' 1663, discusses the forms of images of objects produced by mirrors. He was well aware of the failure of all attempts to perfect telescopes by using lenses of various curvature, and proposed the form of reflecting telescope which bears his name.

Newton, however, was the first to construct a reflecting telescope, and with it he could see Jupiter's satellites, &c. Encouraged by this he made another of $6\frac{1}{3}$ inches focal length, which magnified thirty-eight times, and this he presented to the Royal Society on the day of his election to the Society in 1671.

To Newton we owe also the idea of employing pitch, used in the working of the surfaces.

A third form of telescope was invented by Cassegrain in 1672. He substituted a small convex mirror for the concave mirror in Gregory's form, and thus rendered the telescope a little shorter.

Short also, from 1730–1768, displayed uncommon ability in the manufacture of

reflecting telescopes, and succeeded in giving true parabolic and elliptic figures to his specula, besides obtaining a high degree of polish upon them. In Short's first telescopes the specula were of glass, as suggested by Gregory, but it was not until after Liebig's discovery of the process of depositing a film of metallic silver upon a glass surface from a salt in solution that glass specula became almost universal, and thus replaced the metallic ones of earlier times.

Shortly after the announcement of Liebig's discovery Steinheil[1]—and later, independently, Foucault[2]—proposed to employ glass for the specula of telescopes, and, as is well known, this is done in all the large reflectors of to-day.

I now propose to deal with the various steps in the development of the telescope, which have resulted in the three forms that I take as examples of the highest development at the present time. These are the Yerkes telescope at Chicago, my own 5-foot reflector, and the telescope recently erected at the Paris Exhibition, dealing not only with the mountings, but with the principles of construction of each. When the telescope was first used all could be seen by holding it in the hand. As the magnifying power increased some kind of support would become absolutely necessary, and this would take the form of the altitude and azimuth stand, and the motion of the heavenly bodies would doubtless suggest the parallactic or equatorial movement, by which the telescope followed the object by one movement of an axis placed parallel to the pole. This did not come, however, immediately. The long-focus telescopes of which I have spoken were sometimes used with a tube, but more often the object-glass was mounted in a long cell and suspended from the top of a pole, at the right height to be in a line between the observer and the object to be looked at; and it was so arranged that by means of a cord it could be brought into a fairly correct position. Notwithstanding the extreme awkwardness of this arrangement most excellent observations were made in the seventeenth century by the users of these telescopes. Then the achromatic telescope was invented and mechanical mountings were used, with circles for finding positions, much as we have them now. I have already mentioned the rivalry between the English and German forms of mountings, and Airy's preference for the English form. The general feeling amongst astronomers has, however, been largely in favour of the German mounting for refractors, due, no doubt, to a great extent, to the enormous advance in engineering skill. We have many examples of this form of mounting. A list of the principal large refracting and reflecting telescopes now existing is given at the end of this Address. All the refractors in this list, with the exception of the Paris telescope of 50 inches, and the Greenwich telescope of 28 inches, are mounted on the German form. Some of these carry a reflector as well as, for instance, the telescope lately presented to the Greenwich Observatory by Sir Henry Thompson, which, in addition to a 26-inch refractor, carries a 30-inch reflector at the other end of the declination axis, such as had been previously used by Sir William Huggins and Dr. Roberts; the last, and perhaps the finest, example of the German form being the Yerkes telescope at Chicago.

The small reflector made by Sir Isaac Newton, probably the first ever made, and now at the Royal Society, is mounted on a ball, gripped by two curved pieces, attached to the body of the telescope, which allows the telescope to be pointed in any direction. We have not much information as to the mounting of early reflectors. Sir William Herschel mounted his 4-foot telescope on a rough but admirably planned open-work mounting, capable of being turned round, and with means to tilt the telescope to any required angle. This form was not very suitable for picking up objects or determining their position, except indirectly; but for the way it was used by Sir William Herschel it was most admirably adapted: the telescope being elevated to the required angle, it was left in that position, and became practically a transit instrument. All the objects passing through the field of view (which was of considerable extent, as the eyepiece could be moved in declination) were observed, and their places in time and declination noted, so that

[1] *Gaz. Univ. d'Augsburg*, March 24, 1856.
[2] *Comptes Rend.*, vol. xliv, February 1857.

the positions of all these objects in the zone observed were obtained with a considerable degree of accuracy. It was on this plan that Sir John Herschel made his general catalogue of nebulæ, embracing all the nebulæ he could see in both hemispheres; a complete work by one man that is almost unique in the history of astronomy.

Sir William Herschel's mounting of his 4-foot reflector differs in almost every particular from the mountings of the long-focus telescopes we have just spoken of. The object-glass was at a height, the reflector was close to the ground. There was a tube to one telescope, but not to the other. The observer in one case stood on the ground, in the other he was on a stage at a considerable elevation. One pole sufficed with a cord for one; a whole mass of poles, wheels, pulleys, and ropes surrounded the other. In one respect only were they alike—they both did fine work.

Lassell seems to have been the first to mount a reflector equatorially. He, like Herschel, made a 4-foot telescope, which he mounted in this way. Lord Rosse mounted his telescopes somewhat after the manner of Sir William Herschel. The present Earl has mounted a 3-foot equatorially.

A 4-foot telescope was made by Thomas Grubb for Melbourne, and this he mounted on the German plan. The telescope being a Cassegrain, the observer is practically on the ground level. A somewhat similar instrument exists at the Paris Observatory. Lassell's 4-foot was mounted in what is called a fork mounting, as is also my own 5-foot reflector, and this in some ways seems well adapted for reflectors of the Newtonian kind.

We now come to the Paris telescope. This is really the result of the combination of a reflector and a refractor. I cannot say when a plane mirror was first used to direct the light into a telescope for astronomical purposes. It seems first to have been suggested by Hooke, who, at a meeting of the Royal Society, when the difficulty of mounting the long-focus lenses of Huyghens was under discussion, pointed out that all difficulties would be done away with if, instead of giving movement to the huge telescope itself, a plane mirror were made to move in front of it.[1]

The Earl of Crawford, then Lord Lindsay, used a heliostat to direct the rays from the sun, on the occasion of the transit of Venus, through a lens of 40 feet focal length, in order to obtain photographs, and it was also largely used by the American observers on the same occasion.

Monsieur Loëwy at Paris proposed in 1871 a most ingenious telescope made by a combination of two plane mirrors and an achromatic object-glass, which he calls a Coudé telescope, which has some most important advantages. Chief amongst these are that the observer sits in perfect comfort at the upper end of the polar axis, whence he need not move, and by suitable arrangements he can direct the telescope to any part of the visible heavens. Several have been made in France, including a large one of 24 inches aperture, erected at the Paris Observatory, and which has already made its mark by the production of perhaps the best photographs of the moon yet obtained. I have already spoken of Lord Lindsay and his 40-foot telescope, fed, as it were, with light from a heliostat. This is exactly the plan that has been followed in the design of the large telescope in the Paris Exhibition. But in place of a lens of 4 inches aperture and a heliostat a few inches larger, the Paris telescope has a plane mirror of 6 feet and a lens exceeding 4 feet in diameter, with a focal length of 186 feet. The cost of a mounting on the German plan and of a dome to shelter such an instrument would have been enormous. The form chosen is at once the best and cheapest. One of the great disadvantages is that from the nature of things it cannot take in the whole of the heavens. The heliostat form of mounting of the plane mirror causes a rotation of the image in the field of view which in many lines of research is a strong objection. There is much to be said on the other side. The dome is dispensed with; the tube, the equatorial mounting, and the rising floor are not wanted. The mechanical arrangements of importance are confined to the mounting of the necessary machinery to carry the large plane mirror and move it round at the proper rate. The telescope need not have any tube (that to

[1] Lockyer, *Star-gazing*, p. 453.

the Paris telescope is of course only placed there for effect), as the flimsiest covering is enough if it excludes false light falling on the eye end; and more important than all, the observer sits at his ease in the dark chamber. This question of the observer, and the conditions under which he observes, is a most important one as regards both the quality and quantity of the work done.

We have watched the astronomer, first observing from the floor level, then mounted on a high scaffold like Sir William Herschel, Lassell, and Lord Rosse; then starting again from the floor level and using the early achromatic telescope; then, as these grew in size, climbing up on observing chairs to suit the various positions of the eye end of the telescope, as we see in Mr. Newall's great telescope; then brought to the floor again by that excellent device of Sir Howard Grubb, the rising floor. This is in use with the Lick and the Yerkes telescopes, where the observer is practically always on the floor level, though constant attention is needed, and the circular motion has to be provided for by constant movement, to say nothing of the danger of the floor going wrong. Then we have the ideal condition, as in the Equatorial Coudé at the Paris Observatory, where the observer sits comfortably sheltered and looks down the telescope, and from this position can survey the whole of the visible heavens. The comfort of the observer is a most important matter, especially for the long exposures that are given to photographic plates, as well as for continued visual work. In such a form of telescope as that at Paris the heliostat form of mounting the plane mirror is most suitable, notwithstanding the rotation of the image. But there is another way in which a plane mirror can be mounted, namely, on the plan first proposed by Auguste many years ago, and lately brought forward again by Mons. Lippmann, of Paris, and that is by simply mounting the plane mirror on a polar axis and parallel therewith, and causing this mirror to rotate at half the speed of the earth's rotation. Any part of the heavens seen by any person reflected from this mirror will appear to be fixed in space, and not partake of the apparent movement of the earth, so long as the mirror is kept moving at this rate. A telescope, therefore, directed to such a mirror can observe any heavenly body as if it were in an absolutely fixed position so long as the angle of the mirror shall not be such as to make the reflected beam less than will fill the object-glass. There is one disadvantage in the cœlostat, as this instrument is called, and that is its suitability only for regions near the equator. The range above and below, however, is large enough to include the greater portion of the heavens, and that portion in which the solar system is included. Here the telescope must be moved in azimuth for different portions of the sky, as is fully explained by Professor Turner in vol. lvi. of the 'Monthly Notices,' and it therefore becomes necessary to provide for moving the telescope in azimuth from time to time as different zones above or below the equator are observed. No instrument yet devised is suitable for all kinds of work, but this form, notwithstanding its defects, has so many and such important advantages that I think it will obviate the necessity of building any larger refractors on the usual models. The cost of producing a telescope much larger than the Yerkes on that model, in comparison with what could be done on the plan I now advocate, renders it most improbable that further money will be spent in that way. It may be asked, What are the lines of research which could be taken up by a telescope of this construction, and on what lines should the telescope be built? I will endeavour to answer this. All the work that is usually done by an astronomical telescope, excepting very long-continued observations, can be equally well done by the fixed telescope. But there are some special lines for which this form of research is admirably suited, such as photographs of the moon, which would be possible with a reflecting mirror of, say, 200 feet focal length, giving an image of some 2 feet diameter in a primary focus, or a larger image might be obtained either by a longer-focus mirror or by a combination. It might even be worth while to build a special cœlostat for lunar photography, provided with an adjustment to the polar axis and a method of regulating the rate of clock to correct the irregular motion of the moon, and thus obtain absolutely fixed images on the photographic plate.

The advantage of large primary images in photography is now fully recog-

nised. For all other kinds of astronomical photography a fixed telescope is admirably adapted; and so with all spectroscopic investigations, a little consideration will show that the conditions under which these investigations can be pursued are almost ideal. As to the actual form such a construction would take, we can easily imagine it. The large mirror mounted as a cœlostat in the centre; circular tracts round this centre, on which a fan-shaped house can be travelled round to any azimuth, containing all the necessary apparatus for utilising the light from the large plane mirror, so as to be easily moved round to the required position in azimuth for observation. In place of a fan-shaped house movable round the plane mirror, a permanent house might encircle the greater portion round the mirror, and in this house the telescope or whatever optical combination is used might be arranged on an open framework, supported on similar rails, so as to run round to any azimuth required. The simplicity of the arrangement and the enormous saving in cost would allow in any well-equipped observatory the use of a special instrument for special work. The French telescope has a mirror about 6 feet in diameter and a lens of about 4 feet. This is a great step in advance over the Yerkes telescope, and it may be some time before the glass for a lens greater than 50 inches diameter will be made, as the difficulty in making optical glass is undoubtedly very great. But with the plane mirror there will be no such difficulty, as 6 feet has already been made; and so with a concave mirror there would be little difficulty in beginning with 6 feet or 7 feet. The way in which the mirror would be used, always hanging in a band, is the most favourable condition for good work, and the absence of motion during an observation, except of course that of the plane mirror (which could be given by floating the polar axis and suitable mechanical arrangements, a motion of almost perfect regularity).

One extremely important thing in using silver or glass mirrors is the matter of resilvering from time to time. Up to quite recently the silvering of my 5-foot mirror was a long, uncertain, and expensive process. Now we have a method of silvering mirrors that is certain, quick, and cheap. This takes away the one great disability from the silver or glass reflecting telescope, as the surface of silver can now be renewed with greater ease and in less time than the lenses of a large refracting telescope could be taken out and cleaned. It may be that we shall revert to speculum metal for our mirrors, or use some other deposited metal on glass; but even as it is we have the silvered glass reflector, which at once allows an enormous advance in power. To do justice to any large telescope it should be erected in a position, as regards climate, where the conditions are as favourable as possible.

The invention of the telescope is to me the most beautiful ever made. Familiarity both in making and in using has only increased my admiration. With the exception of the microphone of the late Professor Hughes, which enabled one to hear otherwise inaudible sounds, sight is the only sense that we have been able to enormously increase in range. The telescope enables one to see distant objects as if they were at, say, one five-thousandth part of their distance, whilst the microscope renders visible objects so small as to be almost incredible. In order to appreciate better what optical aid does for the sense of sight, we can imagine the size of an eye, and therefore of a man, capable of seeing in a natural way what the ordinary eye sees by the aid of a large telescope, and, on the other hand, the size of a man and his eye that could see plainly small objects as we see them under a powerful microscope. The man in the first case would be several miles in height, and in the latter he would not exceed a very small fraction of an inch in height.

Photography also comes in as a further aid to the telescope, as it may possibly be to the microscope. For a certain amount of light is necessary to produce sensation in the eye. If this light is insufficient nothing is seen; but owing to the accumulative effect of light on the photographic plate, photographs can be taken of objects otherwise invisible, as I pointed out years ago, for in photographs I took in 1883 stars were shown on photographic plates that I could not see in the telescope. All photographs, when closely examined, are made up of a certain number of little dots, as it were, in the nature of stippling, and it is a very inter-

esting point to consider the relation of the size and separation of these dots that form the image, and the rods and cones of the reckoner which determines the power of the eye.

Many years ago I tried to determine this question. I first took a photograph of the moon with a telescope of very short focus (as near as I could get it to the focus of the eye itself, which is about half an inch). The resulting photograph measured one two-hundredth of an inch in diameter, and when examined again with a microscope showed a fair amount of detail, in fact, very much as we see the moon with the naked eye; making a picture of the moon by hand on such a scale that each separate dot of which it was made corresponded with each separate sensitive point of the retina employed when viewing the moon without optical aid, I found, on looking at this picture at the proper distance, that it looked exactly like a real moon. In this case the distance of the dots was constant, making them larger or smaller forming the light or shade of the picture.

I did not complete these experiments, but as far as I went I thought that there was good reason to believe that we could in this way increase the defining power of the eye. It is a subject well worthy of further consideration.

I know that in this imperfect and necessarily brief address I have been obliged to omit the names of many workers, but I cannot conclude without alluding to the part that this Association has played in fostering and aiding Astronomy. A glance through the list of money grants shows that the help has been most liberal. In my youth I recollect the great value that was put on the British Association Catalogue of Stars; we know the help that was given in its early days to the Kew Observatory; and the Reports of the Association show the great interest that has always been taken in our work. The formation of a separate Department of Astronomy is, I hope, a pledge that this interest will be continued, to the advantage of our science.

List of Large Telescopes in existence in 1900.

Refractors 15 inches and upwards	Inches	Refractors 15 inches and upwards	Inches
Paris (Exhibition)	50	Princeton	23·0
Yerkes	40	Mount Etna	21·8
Lick	36	Strassburg	19·1
Pulkowa	30	Milan	19·1
Nice	29·9	(Dearborn) Chicago	18·5
Paris	28·9	Warner Obs., Rochester, U.S.	16 0
Greenwich	28·0	Washburn Observatory, Madison, Wisconsin	15·5
Vienna	27·0	Edinburgh	15·1
Washington	26·0	Brussels	15·1
Leander, McCormick Observatory, Virginia	26·0	Madrid	15·0
Greenwich	26·0	Rio Janeiro	15·0
Newall's, Cambridge	25·0	Paris	15·0
Cape of Good Hope	24·0	Sir William Huggins	15·0
Harvard	24·0	Paris	15·0

Reflectors 2 feet 6 inches and upwards	Ft.	In.	Reflectors 2 feet 6 inches and upwards	Ft.	In.
Lord Rosse	6	0	South Kensington	3	0
Dr. Common	5	0	Crossley (Lick)	3	0
Melbourne	4	0	Greenwich	2	6
Paris	4	0	South Kensington	2	6
Meudon	3	3			

The following Papers were read:—

1. *On the Application of the Electric Telegraph to the Furtherance of Eclipse Research. By* Professor DAVID P. TODD, *Director of the Observatory of Amherst College, U.S.A.*

In 1878 the idea first occurred to the writer[1] of telegraphing eastward in advance of the lunar shadow in order to enable the immediate verification of any possible discovery as of an intramercurian planet without waiting for another eclipse to take place. A scheme of application to the eclipse of 1887 was published,[2] but the feasibility of the method was not demonstrated till the eclipse of January 1889, when the California observations were, by the courtesy of the Western Union Telegraph Company, reported in New York with such celerity as to outstrip completely the motion of the moon's shadow across the earth.[3] A like experiment, only in more practical form, was carried out during the recent eclipse by co-operation with Mr. A. E. Douglass, of the Lowell Observatory, whose station was in Washington, Georgia. Totality there preceded the same phenomenon in Tripoli, the writer's station, by 2 hours 45 minutes. Immediately totality was over, Mr. Douglass reported in full the success of his observations and the instruments with which they were made, his despatch being forwarded at once to Washington and New York, and over the Western Union Company's cables to Penzance. By the courtesy of J. Denison Pender, Esq., Vice-President and Managing Director of the Eastern Telegraph Company, London, the message was forwarded over this company's cables from Penzance to Gibraltar, thence to Malta, and finally to Tripoli, where a special messenger delivered it at once to the writer at the British Consulate. This message was received and read in less than half an hour of absolute time from its leaving Georgia, and more than two hours before totality actually came on at Tripoli. Had the message announced any discovery, there was abundant time to have prepared for its special verification.

The thanks of astronomers are especially due to the managers of these two great telegraph systems for their generous gift of this service, which has now proved conclusively the practicability of communication between remote eclipse stations while the moon's shadow is still upon the earth. It is easy to see how such communication, during the total eclipse of 1882, might have afforded data for the orbit of the comet discovered during that eclipse, and whose path is now unknown.

Similarly, also, application of the land and cable lines of the globe may be of the greatest service in notifying the occurrence of future meteoric showers.

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2. *On the Operation of Eclipse Instruments Automatically. By* Professor DAVID P. TODD, *Director of the Observatory of Amherst College, U.S.A.*

The successful application of automatic machinery to a wide variety of uses and purposes, removing the uncertainty of manual operations, indicates clearly the desirability of its application to the photography of solar eclipses.

Three distinct systems of controlling the mechanical movements of such instruments are feasible, the capabilities of all of which I have tested within recent years:

(*a*) The pneumatic system devised and built for the U.S. Eclipse Expedition to West Africa, 1889.[4]

The power requisite for the individual movements of shutters and plate-holders was obtained by small collapsible pneumatic 'pockets,' connected with a

[1] *Washington Astronomical Observations for* 1876, Appendix iii. p. 351.
[2] *American Journal of Science*, vol. cxxxiii. p. 226.
[3] *Total Eclipses of the Sun*, by Mrs. Todd (Sampson Low, Marston, & Co., 1900) pp. 164–173.
[4] *Monthly Notices* R.A.S., vol. l. p. 380.

large exhaust bellows by lead tubes of small calibre. The operation of the pockets was controlled through a pneumatic commutator, the control sheet being of paper, and having perforations at such points as corresponded to the mechanism or instrument desired. This sheet unwound from the barrel of an ordinary chronograph, which thereby not only regulated the exposures, but recorded their exact times. Twenty-two photographic instruments were controlled by this scheme of operation at Cape Ledo, West Africa, on December 22, 1889.

(*b*) The electric system devised and built for the Amherst Eclipse Expedition to Japan, 1896, through the liberality of Messrs. Willis and Arthur James, of New York, who sent the expedition out in their yacht *Coronet*.[1] The power requisite for the automatic movements was here derived for the most part from spiral springs, the recoil of which was governed by specially devised escapements operated by ordinary electro-magnets. The control currents were sent through a commutator [2] which was originally a chronograph, the cylinder being replaced by a copper barrel, in which pins were inserted at suitable points for making contacts with the teeth of a copper comb. Thus, as in the pneumatic system, the commutator regulated the exposures and recorded their times as well. Twenty photographic instruments were controlled by this scheme of operation at Esashi, Japan, on August 9, 1896.

(*c*) The mechanical system, devised and built for the expedition to Tripoli, 1900, and at the charges of Mr. Percival Lowell, of Boston. By the courtesy of the Hon. T. S. Jago, H.B.M.'s Consul-General at Tripoli, the station was established on the terrace or roof of the British Consulate. This location afforded, among other advantages, an exceptional chance of utilising gravity as a motive power for the mechanical operation of shutters and plate-holders by means of cords wound upon pulleys which turned the axles, the cords being pulled by small weights which descended within the interior court of the Consulate. This system not having been invented until after my arrival in Tripoli, its construction was necessarily crude and provisional. In addition to the help of native artisans I had the very efficient assistance of Messrs. W. H. Venables and W. F. Riley, of the English colony in Tripoli. The commutator was again a barrel, improvised from a large oil-drum, and turned by a cord and heavy weight, its speed being regulated to the requisite accuracy by a fan governor. By the courtesy of Mr. James A. Doughan this was built in the machine shops of Messrs. Perry, Bury, & Company. From the commutator barrel there unwound also seven cords which passed over pulleys to the various mechanical movements of the shutters and plate-barrels, held in position by escapements similar to those used in Japan for the previous eclipse; and upon these cords were fastened large beads at intervals suited to the exposures required. Each bead in passing the escapement tripped it, thus allowing gravity to advance the movement by a single stage or unit. Seven instruments were operated on this system during the recent eclipse at Tripoli, and about one hundred photographs secured.

Experience with these three systems leads me to the conclusion that with slight modifications the last is simplest and best for the automatic operation of a very few instruments. But a combination of the first and second is best for a large number of instruments, the mechanisms being no more likely to get out of order than the similar movements in the pneumatic and electric action of a modern church organ, and no more likely to fail of the right exposure on the right plate at the right time than such an organ is likely to sound a false or unintended note.

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3. *On the Adaptation of the Principle of the Wedge Photometer to the Biograph Camera in photographing Total Eclipses. By* Professor DAVID P. TODD, *M.A., Ph.D., Director of the Observatory of Amherst College, U.S.A.*

This paper describes an instrument devised for photographing the recent eclipse —both the slender partial phases and the corona on a single film, with correctly

[1] *The Astrophysical Journal*, vol. v., p. 318.

[2] *Stars and Telescopes*, by Professor David P. Todd (Sampson Low, Marston, & Co., 1900), p. 363.

graduated exposures for each. Just in front of the film is mounted a positive wedge of yellow optical glass, backed with an equivalent negative wedge of plain optical glass, the whole having a sliding motion lengthwise. The necessary thickness and length of the wedges are first found by experiment on the sun, entirely obscured artificially by an occulting disc, excepting only the extreme limb. Through a ruby aperture in the camera the observer watches the gradually diminishing eclipse crescent on the film, and racks the wedge along, keeping the intensity of the image as nearly as possible constant. The biograph films of the recent eclipse, taken by Mr. J. N. Maskelyne, F.R.A.S., indicate the necessity of this great reduction of the strong light of the crescents, to avoid solarisation; and show further the ease with which the inner coronal ring can be photographed, long before and after totality.

4. *On the 'Square-shouldered' Aspect of Saturn.* *By* E. M. Antoniadi, *F.R.A.S.*

The author accounts for the abnormal figure assumed by Saturn, under a slight opening of the ring system, by the existence of the planet's dark polar caps, checking irradiation along the minor axis of the disc.

5. *On the Types of Sun-spot Disturbances.* *By* Rev. A. L. Cortie, *F.R.A.S.*

As an aid to researches connected with sun-spots an attempt has been made to classify them according to some prevailing typical forms. For this purpose the Stonyhurst drawings of the solar surface for the last twenty years have been carefully examined. From these it would follow that spots appear as scattered groups of small spots, as trains of spots, as composite groups consisting of three or more larger spots, as single spots of round and regular outline which may or may not be accompanied by smaller companions, and as single spots of irregular outline at times accompanied by a train of small companions, or with outliers not arranged in the form of a train. The chief type, however, of which the above-mentioned are in most, probably in all, cases but phases, is the double-spot formation, with a train of smaller spots between the two principal spots of the group. In this form the principal spot, which eventually becomes a round spot of regular outline, is generally the leading spot; but in some cases it is the following spot, while in other yet rarer cases both the chief spots develop as regular spots. The mode of development of this leading type is described in detail. The following are suggested as the types which will be probably found to cover every case that may arise.

Type I. A group of a few scattered small spots.
Type II. The two-spot formation.
Type II. a. In which the leader is the principal spot.
Type II. b. In which the following spot is the principal spot.
Type II. c. In which both spots are more or less equal.
Type III. A train of spots.
Type III. a. With well-defined principal spots.
Type III. b. Without well-defined principal spots, but mostly penumbral patches with scattered irregular umbræ.
Type IV. Single spots.
Type IV. a. A single spot of round and regular outline.
Type IV. b. A single spot of round and regular outline, with small companions.
Type IV. c. A single spot of irregular outline.
Type IV. d. A single spot of irregular outline with a train of small companions.

Type IV. e. A single spot of irregular outline with small companions not in a train.

Type V. An irregular group of larger spots.

As an example, the process of formation and life-history of a composite disturbance which crossed the solar disc five times during the period May 14–September 4, 1887, could be succinctly described as follows:

I. II. b. | IV. d. IV. a. | IV. a. IV. d. IV. a. | IV. a. I. II. a. | I.

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6. *On a Cheap Form of Micrometer for determining Star Positions on Photographic Plates. By* H. H. TURNER, *M.A., F.R.S., Savilian Professor.*

The experience of those who have been working at the Astrographic Chart shows that for measuring star photographs a *réseau* is practically indispensable. The *réseaux* made by M. Gautier of Paris may be treated as sensibly correct for nearly all purposes. The cost is between 2*l.* and 5*l.*, according to the number of lines ruled; and this initial expense is in any case necessary. But since a photographic copy is often as good as the original, this expense might be shared between two or three workers, or borne by some society, which could distribute copies for a few shillings each to its members.

Given the *réseau,* the rest of the micrometer can be made at a very small expense (say 30*s.* at most) with wood, glass, and paper. Of course, some convenience is sacrificed and a little accuracy lost. The micrometers in use at the Cape of Good Hope cost 180*l.* apiece; the duplex micrometer used at Greenwich about 100*l.*; even the simple form used at Oxford costs 30*l.* It is not to be supposed that nothing is gained by such expenditure. But with a very simple form of instrument such as that exhibited, which a man could make for himself or with a little assistance from any carpenter, excellent work can be done.

The chief part of the instrument is the microscope with scale in the eyepiece. Most people have some old microscope which would do quite well, and in any case a cheap one is all that is necessary. The scale in the eyepiece can be made photographically, drawing the scale on a large sheet of cardboard and taking a miniature photograph of it.

The plate-holder is merely a sheet of glass on which the plate can be easily moved backwards and forwards. The screws required for slow motion and clamping may be ordinary electrical binding-screws or something similar; the counterpoises bags of shot; the reflector a penny mirror, and so on.

To measure photographs which have no *réseau* already impressed upon them, a photographic copy of a *réseau* may be bound up in contact with the plate in the manner of a lantern slide. Attention may, however, be directed to a method of impressing the *réseau* on such plates which have been already developed and fixed,[1] due to M. Bourget, of the Toulouse Observatory.

TUESDAY, SEPTEMBER 11.

The following Papers were read:—

1. *Comparison of Prominence and Corona Photographs taken at Santa Pola, Spain, and Wadesboro, in North Carolina, during the Total Solar Eclipse of May* 28, 1900. *By* WILLIAM J. S. LOCKYER, *M.A., Ph.D.*

This paper consists of a comparison of photographs taken at eclipse stations, 5,000 miles distant from each other, namely, Santa Pola and Wadesboro.

[1] Given in the *Observatory*, May 1900, p. 223; and in the *Bulletin Astronomique*, March 1900.

It was found that during the two and a half hours' difference of time between the times of totality the main prominences had changed considerably in shape and form, but the polar rifts at the north polar region did not undergo any alteration.

The comparison has further led the author to advocate the employment of long-focus cameras for such eclipse work, and to eliminate the necessity of enlargement afterwards.

An explanation is also given to account for the extreme sharpness of the lunar limb on one of the long-exposure photographs, the chief argument employed being the very rapid diminution of intensity of the corona as the outer layers are reached.

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2. *Description of the New Photographic Equatorial of the Cambridge Observatory.* *By* A. R. Hinks, *M.A.*

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3. *Diagram for Planning Observations of Eros at the Opposition of* 1900–1. *By* A. R. Hinks, *M.A.*

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4. *On some Points in connection with the Photography of a Moving Object.* *By* W. E. Plummer.

I have recently had occasion to make some investigations in connection with the theory of Comet 1899, I. The object of the present paper is not to call attention to the form of the orbit, so that that point need not be considered.

But in the course of the examination of the observations I was led to compare a series of places of the comet obtained under the superintendence of the Astronomer Royal, by means of photography with the Thompson Equatorial.

There is, so far as I know, no series of equal length in which the places of a moving object have been determined by photography, and it seemed desirable to investigate the peculiarities with some care.

The series extends from May 25 to June 16, 1899, during which time the comet passed over some 80° of R.A. and 30° of declination.

It is not usual to compare the final elements with individual observations, but only with the normal places. The photographed places have therefore been compared with the preliminary orbit, in this case an hyperbola; and the small deviations, which are removed by the solution of the Equations of Condition, are displayed in the comparison.

But for the purposes of the present investigation it is sufficient to remove these discrepancies by any convenient interpolation formula, and so obtain the deviations of the observations from the true path of the comet.

When this is effected the following deviations are noticeable:—

1899	$d\alpha \cos \delta$	$d\delta$	1899	$d\alpha \cos \delta$	$d\delta$
	″	″		″	″
May 25 . .	− 4·2	−0·7	June 9 . .	−13·9	−4·6
„ 26 . .	− 6·0	−0·9	„ 10 . .	+ 3·7	−7·6
„ 29 . .	+ 1·8	−1·0	„ 10 . .	+ 3·4	−5·1
„ 30 . .	− 1·7	−1·6	„ 11 . .		−9·4
„ 31 . .	− 1·9	0·0	„ 12 . .	+11·1	+9·2
June 2 . .	+ 1·4	−0·6	„ 15 . .	+ 7·3	−0·3
„ 5 . .	+ 3·1	−1·9	„ 16 . .	+ 3·6	+3·8
„ 6 . .	− 3·6	+1·5			

The probable error of a single observation, derived simply from the disagreement from the mean, is, in the case of α, $\pm 4''{\cdot}16$, and in δ, $\pm 2''{\cdot}85$.

There seems no *prima facie* reason why the right ascension coordinate should not be determined with the same accuracy as the declination if the epoch of observation is successfully established.

The declinations in the early part of the series are eminently satisfactory; in that part the motion was very small in δ. Towards the end, when the comet was moving quicker, the agreement is not so satisfactory.

The right ascension varied most rapidly at the beginning of the series, and the agreement would have been more satisfactory throughout, though more noticeable at the beginning, if the epoch of observation had been some seconds later.

It is a very difficult matter to determine the proper time of exposure, since the first few seconds in the photograph of a faint object do not seem to be used in the blackening of the film.

The importance of this point in the photographs of Eros recommended by the International Comité de la Carte du Ciel will not escape the attention of astronomers.

There is another point: how do these observations compare with those made micrometrically in a typical observatory? To illustrate this I select that of Strassburg, where the observations are of unusual excellence, and where the focal length of the instrument is fairly comparable with that of the Greenwich telescope. The series of Strassburg within the same dates, and over which the same interpolation formula is available, is not quite so long, but fairly comparable. The Greenwich places rest in every case, it is believed, on the positions of three stars, the Strassburg never on more than two, and sometimes on a single comparison. The error in the star's place is therefore more effective. The errors are as follows:—

1899	$d\alpha \cos \delta$ ″	$d\delta$ ″	1899	$d\alpha \cos \delta$ ″	$d\delta$ ″
May 27 . .	+5·9	−0·5	June 8 . .	+1·4	−7·2
„ 31 . .	−6·5	+1·0	„ 10 . .	−1·4	+2·9
June 1 . .	−2·4	−0·1	„ 12 . .	+4·5	+0·6
„ 5 . .	+3·9	+0·9	„ 16 . .	+1·8	+1·0
„ 7 . .	−0·8	+0·8			

The probable error of a single observation here amounts to

$$\pm 2''{\cdot}68 \text{ and } \pm 1''{\cdot}91$$

which is less than that of the Greenwich observation in approximately the proportion of 3 to 2.

Pending further experiments, which I believe are to be carried out by photographic experts at the Paris Observatory, the importance of this comparison in the matter of the Eros observations will not be left out of sight.

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5. *On Needle-hole Maps for Meteor Observation.* *By* J. C. W. Herschel.

1. For an *original map* the stars are plotted out on squared millimetre paper to the scale of 1 dm = 45° by Professor Turner's formula,[1] primarily devised for the plates of the Astrographic Chart.

As a check there is used

$$\xi \cot (a - \mathrm{A}) = \sin \mathrm{P} - \eta \cos \mathrm{P}.^{2}$$

2. *The paper for the copies* is sky-blue on one side and white on the other, on which the meteors' paths and descriptions are written.

The needles used are the ordinary commercial needles Nos. 2–12 for magnitudes 1·5 to 4·0 by steps of quarter magnitudes. No. 12 is also used for all stars below 4·0, and an extra large needle for superior stars. The points are ground flat and the needles set in handles. The holes made are round and clean.

[1] *Monthly Notices*, R.A.S., 1894, vol. liv., November.

[2] For $\alpha - \mathrm{A} = 90°$, when the formula is indeterminate, $\xi = \dfrac{\tan p}{\cos \mathrm{P}}$.

Representing light as area, these stars approximate very happily to steps of quarter magnitudes.

Half-a-dozen sheets are laid, blue side down, on a sheet of lead, the original map laid over them, and the stars punched through with the proper-sized needles.

3. At night a copy is laid on a writing-desk with a sloping ground glass top, and illuminated with a night light, which also keeps them dry.

The meteor track (when observed) is marked in pencil along a celluloid ruler with a blackened bevel-edge, which, being transparent, does not hide the configuration of the stars on the map.

4. *Observing.* After comparing my watch with Greenwich time, I sit back in a hammock chair with the illuminated map beside me, a pencil and ruler handy. I find I can hold my eye far more steadily on the meteor's place than a wand held in the hand, which I therefore do not use. I cannot usefully extend my field beyond 45° on either side of the point facing me, except for bright meteors. I let my eyes continually rove about, and when a meteor appears I fasten on it at once, and all the stars fade out; but only for an instant during which I am free to observe the *magnitude*, *colour*, *speed*, and *streak*. Presently the nearest stars begin to glimmer out again and set themselves as a framework round the place of the meteor. But I do not look away at them till I have thoroughly impressed a mental picture of the meteor as part of the scene before me. Whilst doing so I estimate its *duration.* But the most important thing is the *direction.* I follow its line cautiously backwards and forwards, prolonging it until I find suitable reference stars: either, that the line lies over a star—or passes a degree or two from it—or cuts the distance between two stars in a certain proportion. Thus I get two reference points some ten or twenty degrees apart. Next I define to myself the *length* of path as starting and ending on the line joining two stars, or so many degrees before or after that line.

Returning to the estimation of duration, I use Professor Herschel's excellent method of repeating the alphabet over at the rate of five letters to the second, leaving out W—the only letter not monosyllabic.

Now I look at my watch and note the *time of appearance.*

As to the advisability of using maps at all, if the observer knows the stars by heart in configuration and by name, he may very well dispense with maps, &c., describing the meteor and defining its position in words in a notebook in the dark, while still looking at the star lest he miss another meteor. But not many have such knowledge: and the conciseness of the record —a single line on the map—recommends itself compared with a description needing many words. To look away from the sky, down on the map, is a relief to the eye—at the cost, it is true, of possibly losing a meteor, though it must be difficult to go on writing down the description of one meteor while studying another.

Looking down therefore on the map, I set the transparent ruler to the best of my judgment, guiding myself by the reference points I have decided upon, and run a pencil along for the length of path, finishing with a half arrow-head to show the direction, and write the time alongside, and the description at the edge of the map; taking the line back also lightly towards the radiant. It is astonishing how slight a shift satisfies or dissatisfies one, but it is worse than useless to look up again at the sky.

Next day the end points of the paths are read off for tabulation through a 'spider web' of R.A. and Decl. lines on tracing cloth laid over the map.

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6. *Stationary Meteor Radiants.* *By* G. C. Bompas, *F.R.A.S.*

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7. *Cosmic Evolution.* *By* Prof. A. W. Bickerton.

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8. *Duration of Totality of the Solar Eclipse of May 28, 1900.* *By* C. T. Whitmell.

The Paper included the following table:—

No.	Locality	Longitude	Latitude	Duration		Excess Predicted minus Observed	Observers
				Predicted	Observed		
		° ′	° ′	s	s	s	
1	Ovar	8 38 W.	40 50 N.	92·7	84·5	8·2	Christie
2	Plasencia	6 7 „	40 3 „	88·0	82·0	6·0	Downing
3	Coria	6 30 „	39 54 „		80·0		
4	Naval-moral	5 34 „	39 52 „	87·0	80·0	7·0	Whitmell
5	Navaher-mosa (near)	(4 29 „)	(39 40 „)		80·0		
6	Santa Pola	0 30 „	38 13 „	79·0			
7	Alicante	(0 25 „)	(38 20 „)		68·0		
8	Algiers Obsy.	3 2 E.	36 48 „	67·0+	64·0	3·0	Turner
9	Algiers, Hotel	(3 4 „)	(36 47 „)	67·3−	62·5	4·8	Crommelin
10	Cape Matifou	3 15 „	36 48 „	71·0			
11	Menerville	3 35 „	36 43 „	71·0			

9. *Duration of Annularity in a Solar Eclipse.* *By* C. T. Whitmell, *M.A., B.Sc.*

10. *On the Connection between Latitude-variation and Terrestrial Magnetism.* *By* J. Halm.

The following propositions were advanced:—

I. The changes in the motion of the pole of rotation of the earth round the pole of figure are in intimate connection with the variations of the earth-magnetic forces.

II. Inasmuch as the latter phenomena are in a close relation with the state of solar activity, the motion of the pole is also indirectly dependent on the dynamical changes taking place at the sun's surface.

III. The distance between the instantaneous and mean poles decreases with increasing intensity of earth-magnetic disturbance.

IV. The length of the period of latitude variation increases with increasing intensity of earth-magnetic disturbance.

V. In strict analogy with the phenomena of auroræ and of magnetic disturbance, the influence of the eleven years' period of sun-spots, as well as of the 'great' period, is clearly exhibited in the phenomenon of latitude-variation; and the same deviations from the solar curve as are manifested by the auroræ are also evident in the motion of the pole.

VI. The half-yearly period of the earth-magnetic phenomena influences the motion of the pole of rotation in such a way that its path, instead of being circular, assumes the form of an ellipse, having the mean pole at its centre.

VII. The half-yearly period also explains the conspicuous fact of a rotation of the axes of the ellipse in a direction opposite to that of the motion of the pole.

Section B.—CHEMISTRY.

President of the Section.—Professor W. H. Perkin, Jun., Ph.D., F.R.S.

THURSDAY, SEPTEMBER 6.

The President delivered the following Address:—

The Modern System of Teaching Practical Inorganic Chemistry and its Development.

In choosing for the subject of my Address to-day the development of the teaching of practical inorganic chemistry I do so, not only on account of the great importance of the subject, but also because it does not appear that this matter has been brought before this Section, in the President's Address at all events, during the last few years.

In dealing generally with the subject of the teaching of chemistry as a branch of science it may be well in the first place to consider the value of such teaching as a means of general education, and to turn our attention for a few minutes to the development of the teaching of science in schools.

There can be no doubt that there has been great progress in the teaching of science in schools during the last forty years, and this is very evident from the perusal of the essay, entitled 'Education: Intellectual, Moral, and Physical,' which Herbert Spencer wrote in 1859. After giving his reasons for considering the study of science of primary importance in education, Herbert Spencer continues: 'While what we call civilisation could never have arisen had it not been for science, science forms scarcely an appreciable element in our so-called civilised training.'

From this it is apparent that science was not taught to any appreciable extent in schools at that date, though doubtless in some few schools occasional lectures were given on such scientific subjects as physiology, anatomy, astronomy, and mechanics.

Herbert Spencer's pamphlet appears to have had only a very gradual effect towards the introduction of science into schemes of education. For many years chemical instruction was only given in schools at the schoolroom desk, or at the best from the lecture table, and many of the most modern of schools had no laboratories.

The first school to give any practical instruction in chemistry was apparently the City of London School, at which, in the year 1847, Mr. Hall was appointed teacher of chemistry, and there he continued to teach until 1869.[1] Besides the lecture theatre and a room for storing apparatus, Mr. Hall's department

[1] Mr. A. T. Pollard, M.A., Head Master of the City of London School, has kindly instituted a search among the bound copies of the boys' terminal reports, and informs me that in the School form of Terminal Report a heading for Chemistry was introduced in the year 1847, the year of Mr. Hall's appointment.

contained a long room, or rather passage, leading into the lecture theatre, and closed at each end with glass doors. In this room, which was fitted up as a laboratory, and used principally as a preparation room for the lectures, Mr. Hall performed experiments with the few boys who assisted him with his lectures. As accommodation was at that time strictly limited, he used to suggest simple experiments and encourage the boys to carry them out at home, and afterwards he himself would examine the substances which they had made.

From this small beginning the teaching of chemistry in the City of London School rapidly developed, and this school now possesses laboratories which compare favourably with those of any school in the country.

The Manchester Grammar School appears to have been one of the first to teach practical chemistry. In connection with this school a small laboratory was built in 1868: this was replaced by a larger one in 1872, and the present large laboratories, under the charge of Mr. Francis Jones, were opened in 1880.

Dr. Marshall Watts, who was the first science master in this school, taught practical chemistry along with the theoretical work from the commencement in 1868.

As laboratories were gradually multiplied it might be supposed that boys were given the opportunity to carry out experiments which had a close connection with their lecture-room courses. But the programme of laboratory work which became all but universal was the preparation of a few gases, followed by the practice of qualitative analysis. The course adopted seems to have been largely built up on the best books of practical chemistry in use in the colleges at that time; but it was also, no doubt, largely influenced by the requirements of the syllabus of the Science and Art Department, which contained a scheme for teaching practical chemistry.[1] Even down to quite recent times it was in many schools still not considered essential that boys should have practical instruction in connection with lectures in chemistry.

A Report issued in 1897 by a special Committee appointed by the Technical Education Board of the London County Council adduces evidence of this from twenty-five secondary schools in London, in which there were 3,960 boys learning chemistry. Of these 1,698 boys, or 43 per cent., did no practical work whatever;

[1] I find on inquiry at the Board of Education that practical work in qualitative analysis formed part of the examinations for teachers' certificates in inorganic chemistry which were held at South Kensington annually in November from 1859 to 1866 inclusive. A syllabus for this examination was published in the *Science Directory* for 1859, the following portion of which relates to practical work:—'Outlines of Qualitative Analysis. Reactions of the principal mineral acids and bases. Course pursued in the application of these reactions to the analysis of a mixture of several acids and bases.' Three questions were set involving the qualitative analysis of (1) a mixture of two acids and two bases soluble in water or acids; (2) a mixture of two acids and two bases partly or entirely insoluble in water and acids; (3) more complicated mixtures. The candidates for these certificates were not examined in practical organic chemistry.

The first practical examination in chemistry for students was held by the Board in 1878, in the Advanced Stage and Honours only of inorganic chemistry, the analysis of simple salts being prescribed in the former, and of complex mixtures in the latter examination. Previously to this, however, special extra payments had been made on the results of instruction in practical chemistry, and questions dealing with laboratory practice were set in the ordinary written examinations in chemistry, and were 'as far as possible so framed as to prevent answers being given by pupils who had obtained their information merely from books and oral instruction.' The Inspector, however, when visiting the schools might call upon any students who were to be presented for these special grants to perform experiments in his presence. This system was continued in the elementary stage of inorganic chemistry till 1882.

In 1878 the syllabus for organic chemistry extended these two methods of practical examination to that branch of the subject. In the syllabus published in 1882 the present division in all stages of both organic and inorganic chemistry into distinct theoretical and practical examinations was commenced.

955 boys, or 24 per cent., did practical work, consisting of a certain amount of preparation of gases, together with qualitative analysis; but of these latter 743, or 77 per cent., had not reached the study of the metals in their theoretical work, so that their testing work can have been of little educational value. It was also found that in the case of 655, or 68 per cent. of the total number of boys taking practical work, the first introduction to practical chemistry was through qualitative analysis.

But some years before this Report was issued a movement had begun which was destined to have a far-reaching effect. A Report 'on the best means for promoting Scientific Education in Schools' having been presented to the Dundee Meeting of this Association in 1867, and published in 1868, a Committee of the British Association was appointed in 1887 'for the purpose of inquiring and reporting upon the present methods of teaching chemistry.' The well-known Report which this Committee presented to the Newcastle Meeting in 1889 insisted that it was worth while to teach chemistry in schools, not so much for the usefulness of the information imparted as for the special mental discipline it afforded if the scientific method of investigating nature were employed. It was argued that 'learners should be put in the attitude of discoverers, and led to make observations, experiments, and inferences for themselves.' And since there can be little progress without measurement, it was pointed out that the experimental work would necessarily be largely of a quantitative character.

Professor H. E. Armstrong, in a paper read at a conference at the Health Exhibition five years before this, had foreshadowed much that was in this Report. He also drew up a detailed scheme for 'a course of elementary instruction in physical science,' which was included in the Report of the Committee, and it cannot be doubted that this scheme and the labours of the Committee have had a very marked influence on the development of the teaching of practical chemistry in schools. That this influence has been great will be admitted when it is understood that schemes based on the recommendation of the Committee are now included in the codes for both Elementary Day Schools and Evening Continuation Schools. The recent syllabuses for elementary and advanced courses issued by the Incorporated Association of Headmasters and by the Oxford and Cambridge local boards and others are evidently directly inspired by the ideas set forth by the Committee.

The Department of Science and Art has also adopted some of the suggestions of the Committee, and a revised syllabus was issued by the Department in 1895, in which qualitative analysis is replaced by quantitative experiments of a simple form, and by other exercises so framed 'as to prevent answers being given by students who have obtained their information from books or oral instruction.' This was a very considerable advance, but it must be admitted that there is nothing in the syllabus which encourages, or even suggests, placing the learners in the attitude of discoverers, and this, in the opinion of the Committee of this Association, is vital if the teaching is to have educational value.

Many criticisms have been passed upon the 1889 Report. It has been said that life is much too short to allow of each individual advancing from the known to the unknown, according to scientific methods, and that even were this not so too severe a tax is made upon the powers of boys and girls. In answer to the second point it will be conceded that while it is doubtless futile to try to teach chemistry to young children, on the other hand experience has abundantly shown that the average schoolboy of fourteen or fifteen can, with much success, investigate such problems as were studied in the researches of Black and Scheele, of Priestley and Cavendish and Lavoisier, and it is quite remarkable with what interest such young students carry out this class of work.

It may be well to quote the words which Sir Michael Foster used in this connection in his admirable Presidential Address to this Association in 1899. He said: 'The learner may be led to old truths, even the oldest, in more ways than one. He may be brought abruptly to a truth in its finished form, coming straight to it like a thief climbing over a wall; and the hurry and press of modern life tempt many to adopt this quicker way. Or he may be more slowly guided along

the path by which the truth was reached by him who first laid hold of it. It is by this latter way of learning the truth, and by this alone, that the learner may hope to catch something at least of the spirit of the scientific inquirer.'

I believe that in the determination of a suitable school course in experimental science this principle of historical development is a very valuable guide, although it is not laid down in the 1889 Report of the British Association.

The application of this principle will lead to the study of the solvent action of water, of crystallisation, and of the separation of mixtures of solids before the investigation of the composition of water, and also before the investigation of the phenomena of combustion. It will lead to the investigation of hydrochloric acid before chlorine, and especially to the postponement of atomic and molecular theories, chemical equations, and the laws of chemical combination, until the student has really sufficient knowledge to understand how these theories came to be necessary.

There can be no doubt that this new system of teaching chemistry in schools has been most successful. Teachers are delighted with the results which have already been obtained, and those whom I have had the opportunity of consulting, directly and indirectly, cannot speak too highly of their satisfaction at the disappearance of the old system of qualitative analysis, and the institution of the new order of things. Especially I may mention in this connection the excellent work which is being carried on under the supervision of Dr. Bevan Lean at the Friends' School in Ackworth, where the boys have attained results which are far in advance of anything which would have been thought possible a few years since.

It is, of course, obvious that if a schoolboy is made to take the attitude of a discoverer his progress may appear to be slow. But does this matter? Most boys will not become professional chemists; but if while at school a boy learns how to learn, and how to 'make knowledge'[1] by working out for himself a few problems, a habit of mind will be formed which will enable him in future years to look in a scientific spirit at any new problems which may face him. When school-days are past the details of the preparation of hydrogen may have been forgotten; but if it was really understood at the time that it could not be decided at once whether the gas was derived from the acid or from the metal, or from the water, or in part from the one and in part from the other, an attitude of scepticism and of suspended judgment will have been formed, which will continue to guard from error.

In the new system of teaching chemistry in schools much attention must necessarily be given to weights and measurements; indeed, the work must be largely of a quantitative kind, and it is in this connection that an important note of warning has been sounded by several teachers.[2] They consider, very rightly, that it is important to point out clearly to the scholar that science does not consist of measurement, but that measurement is only a tool in the hand of the inquirer, and that when once sufficient skill has been developed in its use it should be employed only with a distinct object. Measurements should, in fact, be made only in reference to some actual problem which appears to be really worth solving, not in the accumulation of aimless details.

And, of course, all research carried out must be genuine and not sham, and all assumption of the 'obvious' must be most carefully guarded against. But the young scholar must, at the same time, not forget that although the scientific method is necessary to enable him to arrive at a result, in real life it is the answer to the problem which is of the most importance.[3]

Although, then, there has been so much discussion, during the last ten years, on the subject of teaching chemistry in schools, and such steady progress has been made towards devising a really satisfactory system of teaching the subject to young boys and girls, it is certainly very remarkable that practically nothing has been

[1] *Cf.* Professor J. G. Macgregor in *Nature*, September 1899.

[2] *Cf.* H. Picton in *The School World*, November 1899; Bevan Lean, *ibid.*, February 1890.

[3] *Cf.* Mrs. Bryant, *Special Reports on Educational Subjects*, vol. ii. p. 113.

said or written bearing on the training which a student who wishes to become a chemist is to undertake at the close of his school-days at the college or university in which his education is continued.

One of the most remarkable points, to my mind, in connection with the teaching of chemistry is the fact that although the science has been advancing year by year with such unexampled rapidity, the course of training which the student goes through during his first two years at most colleges is still practically the same as it was thirty or forty years ago. Then, as now, after preparing a few of the principal gases, the student devotes the bulk of his first year to qualitative analysis in the dry and wet way, and his second year to quantitative analysis, and, although the methods employed in teaching the latter may possibly have undergone some slight modification, there is certainly no great difference between the routine of simple salt and mixture practised at the present day and that which was in vogue in the days of our fathers and grandfathers.

Since, then, the present system has held the field for so long, not only in this country but also on the Continent, it is worth while considering whether it affords the best training which a student who wishes to become a chemist can undergo in the short time during which he can attend at a college or university. In considering this matter I was led in the first place to carefully examine old books and other records, with the object of finding out how the present system originated, and I think that valuable and interesting information bearing on the subject may be obtained from a very brief sketch of the rise and development of the present system of teaching chemistry, and especially in so far as it bears on the inclusion of qualitative analysis. Unfortunately, it is not so easy to gain a good historical acquaintance with the matter as I at first imagined would be the case, and this is due in a large measure to the fact that so few of the laboratories which took an active part in the development of the present system of chemical training have left any record of the methods which they employed. In this connection I may, perhaps, be allowed to suggest that it would be a valuable help to the future historian if all prominent teachers of chemistry would leave behind them a brief record of the system of teaching adopted in their laboratories, showing the changes which they had instituted, the object of these changes, and the results which followed their adoption.

There is no doubt that the progress of practical chemistry went largely hand in hand with the progress of theoretical chemistry, for as the latter gradually developed, so the necessity for the determination of the composition, first of the best known, and then of the rarer minerals and other substances, became more and more marked.

The analytical examination of substances in the dry way was employed in very early times in connection with metallurgical operations, and especially in the determination of the presence of valuable constituents in samples of minerals. Cupellation was used by the Greeks in the separation of gold and silver from their ores and in the purification of these metals. Geber knew that the addition of nitre to the ore facilitated the separation of gold and silver, and subsequently Glauber (1604–1668) called attention to the fact that many commoner metals could easily be separated from their ores with the aid of nitre.

But it was not till the eighteenth century that any marked progress was made in analysis in the dry way, and the progress which then became rapid was undoubtedly due to the discovery of the blowpipe, and to the introduction of its use into analytical operations. The blowpipe is mentioned for the first time in 1660, in the transactions of the Accademia del Cimento of Florence, but the first to recommend its use in chemical operations was Johann Andreas Cramer in 1739. The progress of blowpipe analysis was largely due to Gahn (1745–1818), who spent much time in perfecting its use in the examination of minerals, and it was he who first used platinum wire and cobalt solution in connection with blowpipe analysis. The methods employed by Gahn were further developed by his friend Berzelius (1779–1848), who gave much attention to the matter, and who with great skill and patience gradually worked out a complete scheme of blowpipe analysis, and published it in a pamphlet, entitled 'Ueber die Anwendung des

Löthrohrs,' which appeared in 1820. After the publication of this work blowpipe analysis rapidly came into general use in England, France, and Germany, and the scheme devised by Berzelius is essentially that employed at the present day.

Indeed, the only notable additions to the methods of analysis in the dry way since the time of Berzelius are the development of flame reactions, which Bunsen worked out with such characteristic skill and ingenuity, and the introduction of the spectroscope.

The necessity for some process other than that of analysis in the dry way seems, in the first instance, to have arisen in quite early times in connection with the examination of drugs, not only on account of the necessity for discovering their constituents, but also as a means of determining whether they were adulterated. In such cases analysis in the dry way was obviously unsuitable, and experience soon showed that the only way to arrive at the desired result was to treat the substance under examination with aqueous solutions of definite substances, the first reagent apparently being a decoction of gallnuts, which is described by Pliny as being employed in detecting adulteration with green vitriol.

The progress made in connection with wet analysis was, however, exceedingly slow, largely owing to the lack of reagents; but as these were gradually discovered wet analysis rapidly developed, especially in the hands of Tachenius, Scheele, Boyle, Hoffman, Margraf, and Bergmann. Boyle (1626–1691) especially had an extensive knowledge of reagents and their application; and, indeed, it was Boyle who first introduced the word 'analysis' for those operations by which substances may be recognised in the presence of one another. Boyle knew how to test for silver with hydrochloric acid, for calcium salts with sulphuric acid, and for copper by the blue solution produced by ammonia.

Margraf (1709–1782) introduced prussiate of potash for the detection of iron, and Bergmann (1735–1784) not only introduced new reagents and new methods for decomposing minerals and refractory substances, such as fusion with potash, digestion with nitric acid or hydrochloric acid, but he also was the first to suggest the application of tests in a systematic way, and, indeed, the method of analysis which he developed is on much the same lines as that in use at the present day. He paid special attention to the qualitative analysis of minerals, and gave careful instructions for the analysis of gold, platinum, silver, lead, copper, zinc, and other ores. The work of Scheele (1742–1786) had indirectly a great influence on qualitative analysis, as, although he did not give a general systematic method of procedure in the analysis of substances of unknown composition, yet the methods which he employed in the examination of new substances were so original and exact as to remain models of how qualitative analysis should be conducted.

Great strides in analytical chemistry in the wet way were made through the work of Berzelius, who, by the discovery of new methods, such as the decomposition of silicates by hydrofluoric acid and the introduction of new tests, greatly advanced the art. He paid special attention to perfecting the methods of analysis of mineral waters, and these researches as well as his work on ores, and particularly his investigation of platinum ores, stamp Berzelius as one of the great pioneers in qualitative and quantitative analytical chemistry.

By the labours of the great experimenters whom I have mentioned qualitative analysis gradually acquired the familiar appearance of to-day, and many books were written with the object of arranging the mass of information which had accumulated, and of thus rendering it available for the student in his efforts to investigate the composition of new minerals and other substances. Among these books may be mentioned the 'Handbuch der analytischen Chemie,' by H. Rose, and especially the well-known analytical text-books of Fresenius, which have had an extraordinarily wide circulation and passed through many editions.

The work of the great pioneers in analytical chemistry was work done often under circumstances of great difficulty, as before the end of the seventeenth century there were no public institutions of any sort in which a practical knowledge of chemistry could be acquired. Lectures were, of course, given from very early times, but it was not until the time of Guillaume François Rouelle (1703–1770), at

the beginning of the eighteenth century, that lectures began to be illustrated by experiments. Rouelle, who was very active as a teacher, numbered among his pupils many men of eminence, such as Lavoisier and Proust, and it was largely owing to his influence that France took such a lead in practical teaching. In Germany progress was much slower, and in our country the introduction of lectures illustrated by experiments seems to have been mainly due to Davy.

When it is considered how slowly experimental work came to be recognised as a means of illustration and education, even in connection with lectures, it is not surprising that in early times practical teaching in laboratories should have been thought quite unnecessary.

The few laboratories which existed in the sixteenth century were built mainly for the practice of alchemy by the reigning princes of the time, and, indeed, up to the beginning of the nineteenth century, the private laboratories of the great masters were the only schools in which a favoured few might study, but which were not open to the public. Thus we find that Berzelius received in his laboratory a limited number of students who worked mostly at research: these were not usually young men, and his school cannot thus be considered as a teaching institution in the ordinary sense of the word.

The first really great advance in laboratory teaching is due to Liebig, who, after working for some years in Paris under Gay-Lussac, was appointed in 1824 to be Professor of Chemistry in Giessen. Liebig was strongly impressed with the necessity for public institutions where any student could study chemistry, and to him fell the honour of founding the world-famed Giessen Laboratory, the first public institution in Germany which brought practical chemistry within the reach of all students.

Giessen rapidly became the centre of chemical interest in Germany, and students flocked to the laboratory in such numbers as to necessitate the development of a systematic course of practical chemistry, and in this way a scheme of teaching was devised which, as we shall see later, has served as the foundation for the system of practical chemistry in use at the present day.

When the success of this laboratory had been clearly established many other towns discovered the necessity for similar institutions, and in a comparatively short time every university in Germany possessed a chemical laboratory. The teaching of practical chemistry in other countries was, however, of very slow growth; in France, for example, Wurtz in 1869 drew attention to the fact that there was at that time only one laboratory which could compare with the German laboratories, namely, that of the École Normale Supérieure.

The earliest laboratory for teaching purposes in Great Britain was that of Thomas Thomson, who, after graduating in Edinburgh in 1799, began lecturing in that city in 1800, and opened a laboratory for the practical instruction of his pupils. Thomson was appointed lecturer in Chemistry in Glasgow University in 1807, and Regius Professor in 1818, and in Glasgow he also opened a general laboratory.

Actual progress in the general establishment of laboratories for the study of chemistry seems to date from the time of Thomas Graham, who in 1830 was appointed Professor of Chemistry at Anderson's College in Glasgow, and in 1837 at University College, London. Whether practical chemistry was taught in Anderson's College at that time I have not been able to ascertain, but there is no doubt that regular courses in testing and systematic analysis were given by Graham from 1837 to the date of his resignation in 1855.

In 1845 the College of Chemistry was founded in London, an institution which under A. W. Hofmann's guidance rapidly rose to such a prominent position, and in 1851 Frankland was appointed to the chair of chemistry in the new college founded in Manchester by the trustees of John Owens, and here he equipped a laboratory for the teaching of practical chemistry. Under Sir Henry Roscoe this laboratory soon became too small for the growing number of chemical students, a defect which was removed when the new buildings of the college were opened in 1873. In 1849 Alexander Williamson was appointed Professor of Practical Chemistry at University College, London, where he introduced the practical methods of Liebig.

Following these examples, the older universities gradually came to see the necessity for providing accommodation for the practical teaching of chemistry, with the result that well-equipped laboratories have been erected in all the centres of learning in this country.

Since Liebig, by the establishment of the Giessen Laboratory, must be looked upon as the pioneer in the development of practical laboratory teaching, it will be interesting to endeavour to obtain some idea of the methods which he used in the training of the students who attended his laboratory in Giessen. From small beginnings he gradually introduced a systematic course of practical chemistry, and a careful comparison shows that this was similar in many ways to that in use at the present day. The student at Giessen, after preparing the more important gases, was carefully trained in qualitative and quantitative analysis; he was then required to make a large number of preparations, after which he engaged in original research.

Although there is, as far as I have been able to ascertain, no printed record of the nature of the quantitative work and the preparations which Liebig required from his students, the course of qualitative analysis is easily followed, owing to the existence of a most interesting book published for the use of the Giessen students.

In 1846, at Liebig's request, Henry Will, Ph.D., Extraordinary Professor of Chemistry in the University of Giessen, wrote a small book, for use at Giessen, called 'Giessen Outlines of Analysis,' which shows clearly the kind of instruction given in that laboratory at the time in so far as qualitative analysis is concerned. This book, which contains a preface by Liebig, is particularly interesting on account of the fact that it is evidently the first Introduction to Analysis intended for the training of elementary students which was ever published. In the preface Liebig writes: 'The want of an introduction to chemical analysis adapted for the use of a laboratory has given rise to the present work, which contains an accurate description of the course I have followed in my laboratory with great advantage for twenty-five years. It has been prepared at my request by Professor Will, who has been my assistant during a great part of this period.'

This book undoubtedly had a considerable circulation, and was used in most of the laboratories which were in existence at that time, and thus we find, for example, that the English translation which Liebig 'hopes and believes will be acceptable to the English public' was the book used by Hofmann for his students at the College of Chemistry. In this book the metals are first divided into groups much in the same way as is done now; each group is then separately dealt with, the principal characteristics of the metals of the group are noted, and their reactions studied. Those tests which are useful in the detection of each metal are particularly emphasised, and the reasons given for selecting certain of them as of special value for the purposes of separating one metal from another.

Throughout this section of the book there are frequent discussions as to the possible methods of the separation, not only of the metals of one group, but of those belonging to different groups; and the whole subject is treated in a manner which shows clearly that Liebig's great object was to make the student think for himself. After studying in a similar manner the behaviour of the principal acids with reagents, the student is introduced to a course of qualitative analysis comprising, 1, preliminary examination of solids; 2, qualitative analysis of the substance in solution.

Both sections are evidently written with the object not only of constructing a system of qualitative analysis, but more particularly of clearly leading the student to argue out for himself the methods of separation which he will ultimately adopt. The book concludes with a few tables which differ considerably in design from those in use at the present day, and which are so meagre that the student could not possibly have used them mechanically.

The system introduced in this book, no doubt owing to the excellent results obtained by its use, was rapidly recognised as the standard method of teaching analysis in most of the institutions existing at that time. Soon the course began to be further developed, book after book was published on the subject, and gradually the teaching of qualitative analysis assumed the shape and form with

which we are all so well acquainted. But the present-day book on qualitative analysis differs widely from 'Giessen Outlines' in this respect, that whereas in the latter the tables introduced are mere indications of the methods of separation to be employed, and are of such a nature that the student who did not think for himself must have been constantly in difficulties, in the book of the present day these tables have been worked out to the minutest detail. Every contingency is provided for; nothing is left to the originality of the student; and that which, no doubt, was once an excellent course has now become so hopelessly mechanical as to make it doubtful whether it retains anything of its former educational value.

The question which I now wish to consider more particularly is whether the system of training chemists which is at present adopted, with little variation, in our colleges and universities is a really satisfactory one, and whether it supplies the student with the kind of knowledge which will be of the most value to him in his future career.

Those who study chemistry may be roughly divided as to their future careers into two groups—those who become teachers and those who become technical chemists. Now, whether the student takes up either the one or the other career, I think that it is clear that the objects to be aimed at in training him are to give him a sound knowledge of his subject, and especially to so arrange his studies as to bring out in every possible way his capacity for original thought.

A teacher who has no originality will hardly be successful, even though he may possess a very wide knowledge of what has already been done in the past. He will have little enthusiasm for his subject, and will continue to teach on the lines laid down by the text-books of the day, without himself materially improving the existing methods, and, above all, he will be unable, and will have no desire, to add to our store of knowledge by original investigation.

It is in the power of almost every teacher to do some research work, and it seems probable that the reason why more is not done by teachers is that the importance of research work was not sufficiently insisted on, and their original faculty was not sufficiently trained, at the schools and colleges where they received their education.

And these remarks apply with equal force to the student who subsequently becomes a technical chemist.

In the chemical works of to-day sound knowledge is essential, but originality is an even more important matter. A technical chemist without originality can scarcely rise to a responsible position in a large works, whereas a chemist who is capable of constantly improving the processes in operation, and of adding new methods to those in use, becomes so valuable that he can command his own terms.

Now, this being so, I think it is extraordinary that so many of the students who go through the prescribed course of training—say for the Bachelor of Science degree—not only show no originality themselves, but seem also to have no desire at the conclusion of their studies to engage in original investigation under the supervision of the teacher. That this is so is certainly my experience as a teacher examiner, and I feel sure that many other teachers will endorse this view of the aud case.

If we inquire into the reason for this deficiency in originality we shall, I think, be forced to conclude that it is in a large measure due to the conditions of study and the nature of the courses through which the student is obliged to pass.

A well-devised system of quantitative analysis is undoubtedly valuable in teaching the student accurate manipulation, but it has always seemed to me that the long course of qualitative analysis which is usually considered necessary, and which generally precedes the quantitative work, is not the most satisfactory training for a student.

There can be no doubt that to many students qualitative analysis is little more than a mechanical exercise: the tables of separation are learnt by heart, and every substance is treated in precisely the same manner: such a course is surely not calculated to develop any original faculty which the student may possess. Then, again, when the student passes on to quantitative analysis, he receives elaborate instructions as to the little details he must observe in order to get an accurate

result; and even after he has become familiar with the simpler determinations he rarely attempts, and indeed has no time to attempt, anything of the nature of an original investigation in qualitative or quantitative analysis. It indeed sometimes happens that a student at the end of his second year has never prepared a pure substance, and is often utterly ignorant of the methods employed in the separation of substances by crystallisation; he has never conducted a distillation, and has no idea how to investigate the nature and amounts of substances formed in chemical reactions; practically all his time has been taken up with analysis. That this is not the way to teach chemistry was certainly the opinion of Liebig, and in support of this I quote a paragraph bearing on the subject which occurs in a very interesting book on 'Justus von Liebig: his Life and Work,' written by W. A. Shenstone (pp. 175, 176).

'In his practical teaching Liebig laid great stress on the producing of chemical preparations; on the students preparing, that is to say, pure substances in good quantity from crude materials. The importance of this was, even in Liebig's time, often overlooked; and it was, he tells us, more common to find a man who could make a good analysis than to find one who could produce a pure preparation in the most judicious way.'

'There is no better way of making one's self acquainted with the properties of a substance than by first producing it from the raw material, then converting it into its compounds, and so becoming acquainted with them. By the study of ordinary analysis one does not learn how to use the important methods of crystallisation, fractional distillation, nor acquire any considerable experience in the proper use of solvents. In short, one does not, as Liebig said, become a chemist.'

One reason why the present system of training chemists has persisted so long is no doubt that it is a very convenient system: it is easily taught, does not require expensive apparatus, and, above all, it lends itself admirably for the purpose of competitive examination.

The system of examination which has been developed during the last twenty years has done much harm, and is a source of great difficulty to any conscientious teacher who is possessed of originality, and is desirous, particularly in special cases, of leaving the beaten track.

In our colleges and universities most of the students work for some definite examination—frequently for the Bachelor of Science degree—either at their own University or at the University of London.

For such degrees a perfectly definite course is prescribed and must be followed, because the questions which the candidate will have to answer at his examination are based on a syllabus which is either published or is known by precedent to be required. The course which the teacher is obliged to teach is thus placed beyond his individual power of alteration, except in minor details, and originality in the teacher is thereby discouraged: he knows that all students must face the same examination, and he must urge the backward man through exactly the same course as his more talented neighbour.

In almost all examinations salts or mixtures of salts are given for qualitative analysis. 'Determine the constituents of the simple salt A and of the mixture B' is a favourite examination formula; and as some practical work of this sort is sure to be set, the teacher knows that he must contrive to get one and all of his students into a condition to enable them to answer such questions.

If, then, one considers the great amount of work which is required from the present-day student, it is not surprising that every aid to rapid preparation for examination should be accepted with delight by the teacher; and thus it comes about that tables are elaborated in every detail, not only for qualitative analysis in inorganic chemistry, but, what is far worse, for the detection of some arbitrary selection of organic substances which may be set in the syllabus for the examination. I question whether any really competent teacher will be found to recommend this system as one of educational value or calculated to bring out and train the faculty of original thought in students.

If, then, the present system is so unsatisfactory, it will naturally be asked,

How are students to be trained, and how are they to be examined so as to find out the extent of the knowledge of their subject which they have acquired?

In dealing with the first part of the question—that is, the training best suited to chemists—I can, of course, only give my own views on the subject—views which, no doubt, may differ much from those of many of the teachers present at this meeting. The objects to be attained are, in my opinion, to give the student a sufficient knowledge of the broad facts of chemistry, and at the same time so to arrange his practical work in particular as to always have in view the training of his faculty of original thought.

I think it will be conceded that any student, if he is to make his mark in chemistry by original work, must ultimately specialise in some branch of the subject. It may be possible for some great minds to do valuable original work in more than one branch of chemistry, but these are the exceptions; and as time goes on, and the mass of facts accumulates, this will become more and more impossible. Now a student at the commencement of his career rarely knows which branch of the subject will fascinate him most, and I think, therefore, that it is necessary, in the first place, to do all that is possible to give him a thorough grounding in all branches of the subject. In my opinion the student is taken over too much ground in the lecture courses of the present day: in inorganic chemistry, for example, the study of the rare metals and their reactions might be dispensed with, as well as many of the more difficult chapters of physical chemistry, and in organic chemistry such complicated problems as the constitutions of uric acid and the members of the camphor and terpene series, &c., might well be left out. As matters stand now, instruction must be given on these subjects simply because questions bearing on them will probably be asked at the examination.

And here perhaps I might make a confession, in which I do not ask my fellow-teachers to join me. My name is often attached to chemistry papers which I should be sorry to have to answer; and it seems to me the standard of examination papers, and especially of Honours examination papers, is far too high. Should we demand a pitch of knowledge which our own experience tells us cannot be maintained for long?

In dealing with the question of teaching practical chemistry it may be hoped, in the first place, that in the near future a sound training will be given in elementary science in most schools, very much on the lines which I mentioned in the first part of this Address. The student will then be in a fit state to undergo a thoroughly satisfactory course of training in inorganic chemistry during his first two years at college. Without wishing in any way to map out a definite course, I may be allowed to suggest that instead of much of the usual qualitative and quantitative analysis, practical exercises similar to the following will be found to be of much greater educational value.

(1) The careful experimental demonstration of the fundamental laws of chemistry and physical chemistry.

(2) The preparation of a series of compounds of the more important metals, either from their more common ores or from the metals themselves. With the aid of the compounds thus prepared the reactions of the metals might be studied and the similarities and differences between the different metals then carefully noted.

(3) A course in which the student should investigate in certain selected cases: (*a*) the conditions under which action takes place; (*b*) the nature of the products formed; (*c*) the yield obtained. If he were then to proceed to prepare each product in a state of purity, he would be doing a series of exercises of the highest educational value.

(4) The determination of the combining weights of some of the more important metals. This is in most cases comparatively simple, as the determination of the combining weights of selected metals can be very accurately carried out by measuring the hydrogen evolved when an acid acts upon them.

Many other exercises of a similar nature will readily suggest themselves, and in arranging the course every effort should be made to induce the student to con-

sult original papers and to avoid as far as possible any tendency to mere mechanical work.

The exact nature of such a course must, however, necessarily be left very much in the hands of the teacher, and the details will no doubt require much consideration; but I feel sure that a course of practical inorganic chemistry could be constructed which, while teaching all the important facts which it is necessary for the student to know, will, at the same time, constantly tend to develop his faculty of original thought.

Supposing such a course were adopted (and the experiment is well worth trying), there still remains the problem of how the student who has had this kind of training is to be examined.

With regard to his theoretical work there would be no difficulty, as the examination could be conducted on much the same lines as at the present time. In the case of the practical examination I have long felt that the only satisfactory method of arriving at the value of a student's practical knowledge is by the inspection of the work which he has done during the whole of his course of study, and not by depending on the results of one or two days' set examination. I think that most examiners will agree with me that the present system of examination in practical chemistry is highly unsatisfactory. This is perhaps not so apparent in the case of the qualitative analysis of the usual simple salt or mixture; but when the student has to do a quantitative exercise, or when a problem is set, the results sent in are frequently no indication of the value of the student's practical work. Leaving out of the question the possibility of the student being in indifferent health during the short period of the practical examination, it not infrequently happens that he, in his excitement, has the misfortune to upset a beaker when his quantitative determination is nearly finished, and as a result he loses far more marks than he should do for so simple an accident.

Again, in attacking a problem he has usually only time to try one method of solution, and if this does not yield satisfactory results he again loses marks; whereas in the ordinary course of his practical work, if he were to find that the first method was faulty he would try other methods until he ultimately arrived at the desired result.

It is difficult to see why such an unsatisfactory system as this might not be replaced by one of inspection, which I think could easily be so arranged as to work well.

A student taking, say, a three years' course for the degree of Bachelor of Science might be required to keep very careful notes of all the practical work which he does during this course, and in order to avoid fraud his notebook could from time to time be initialled by the professor or demonstrator in charge of the laboratory. An inspection of these notebooks could then be made at suitable times by the examiners for the degree, by which means a very good idea would be obtained of the scope of the work which the student had been engaged in, and if thought necessary a few questions could easily be asked in regard to the work so presented. Should the examiners wish to further test the candidate by giving him an examination, I submit that it would be much better to set him some exercise of the nature of a simple original investigation, and to allow him two or three weeks to carry this out, than to depend on the hurried work of two or three days.

The object which I had in view in writing this Address was to call attention to the fact that our present system of training in chemistry does not appear to develop in the student the power of conducting original research, and at the same time to endeavour to suggest some means by which a more satisfactory state of things might be brought about. I have not been able, within the limits of this Address, to consider the conditions of study during the third year of the student's career at college, or to discuss the increasing necessity for extending that course and insisting on the student carrying out an adequate original investigation before granting him a degree, but I hope on some future occasion to have the opportunity of returning to this very important part of the subject. If any of the

suggestions I have made should prove to be of practical value, and should lead to the production of more original research by our students, I shall feel that a useful purpose has been served by bringing this matter before this Section. In concluding I wish to thank Professor H. B. Dixon, Professor F. S. Kipping, and others, for many valuable suggestions, and my thanks are especially due to Dr. Bevan Lean for much information which he gave me in connection with that part of this Address which deals with the teaching of chemistry in schools.

The following Reports and Papers were read:—

1. *Report on the Teaching of Science in Elementary Schools.*
See Reports, p. 187.

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2. *On some Problems connected with Atmospheric Carbonic Anhydride, and on a New and Accurate Method for determining its Amount, suitable for Scientific Expeditions. By* Professor LETTS, *D.Sc., Ph.D., &c., and* R. F. BLAKE, *F.I.C., F.C.S., Queen's College, Belfast.*

Attention is drawn to the variations in the amount of atmospheric carbonic anhydride which correspond with at least 10 per cent. of the total amount, the causes of which are still to a large extent obscure. In the author's opinion the subject is an important one, and is worthy of a systematic investigation by a number of skilled observers working in different localities and employing the same method of determination which shall have been proved to give results which do not vary from the true amount by more than three or four parts per million of air. Among the problems relating to atmospheric carbonic anhydride which the authors think are specially deserving of attention are the following:—

1. *Is Schloesing's Theory Correct?*—Do the oceans really act as regulators of the amount of atmospheric carbonic anhydride by the production or dissociation of earthy bicarbonates according as the amount rises above the normal or falls below it? As consequences of this theory latitude should influence the quantity of atmospheric carbonic anhydride, which ought to be lower in polar than in tropical localities, and the great ocean currents should also have an effect as they pass from warmer to colder regions, or the opposite.

2. *The Influence of Day and Night at Sea.*—To account for the increased quantity of atmospheric carbonic anhydride over land surfaces at night, which most of the observers have found, two theories have been advanced: (*a*) cessation of plant activity in decomposing the gas owing to the absence of light, and (*b*) the streaming out of ground air from the soil owing to the lowering of temperature.

At sea no such influences can be exerted, but an absorption of atmospheric carbonic anhydride may occur at the surface of the water owing to lowering of temperature, thus reversing the land effect.

3. *The Effects of Atmospheric Precipitates, and especially of Snowfall, which appears to increase the amount of Atmospheric Carbonic Anhydride.*—No reasonable theory has been advanced to account for this curious phenomenon, and it would be interesting to ascertain whether it occurs at sea as well as on land; and the same remark would apply to fog and rain, both of which appear to affect the amount also.

Other supposed causes of variation are worth studying, such as the effects of the seasons, direction and force of the winds, the prevailing type of weather, &c. But those which the authors think most interesting are such as a scientific mission would be under peculiarly favourable conditions for observing, and especially the proposed Antarctic expeditions.

In a memoir of the authors recently published in the 'Proceedings of the Royal Dublin Society' (vol. ix. N.S., Part II. No. 15) a modification of Pettenkofer's

process for determining atmospheric carbonic anhydride is described by means of which results of great accuracy may be obtained. Thus in the final set of test experiments with artificial mixtures of purified air and carbonic anhydride in known volumes a mean error (in six determinations) of about 1 per cent. of the gas was found, corresponding with some four parts per million of air taken.

For use by a scientific expedition it seemed, however, to the authors that a different process is required in which the operations at the place of observation should be as simple as possible, and of such a nature as to permit of the actual determinations being made at any convenient time later, when the resources of a properly equipped laboratory are available

The authors have accordingly devised a method which fulfils these conditions, and which is simple and accurate. On the one hand it resembles Pettenkofer's process in that a relatively small volume of air is examined (about six litres), while, on the other, Müntz and Aubin's principle is adopted of absorbing the carbonic anhydride by caustic potash solution and afterwards liberating it by ebullition *in vacuo* with an acid and measuring its volume in a suitable gas analysis apparatus.

A series of sealed tubes is prepared in the laboratory, each tube containing an accurately measured volume of weak potash solution (the amount of combined carbonic anhydride which such a solution always contains having been ascertained for a given stock).

The only operations which have to be performed at the place of observation are the collection of the air sample in a suitable receiver; the transfer of the contents of one of the sealed tubes to the latter, and after absorption of the atmospheric carbonic anhydride their retransfer as far as possible to the same tube, which will be again sealed. The tubes can of course be kept for an indefinite period both before and after their contents have been thus treated, and the determination of the absorbed carbonic anhydride made, when convenient, with an aliquot portion of their contents. The experiments made to test the accuracy of the new method were satisfactory. Artificial mixtures of purified air and carbonic anhydride in definite volumes were employed (the two being in about the proportion they occur in ordinary air). Five determinations in such mixtures gave a mean error of 1·3 per cent. of the carbonic anhydride taken equivalent to four parts per million of air.

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3. *On the Distribution of Chlorine in West Yorkshire.* *By* WILLIAM ACKROYD, *F.I.C.*

The present observations are to be regarded as the preliminaries to an attempt to construct isochlors for this part of Yorkshire. The subject is one of acknowledged importance, Professor Mason remarking:—'State maps, such as those issued for the States of Massachusetts and Connecticut, are most valuable, and their construction is well worth the expenditure of public money.'[1] Although the work is not far enough advanced for map construction, the figures which follow, and observations thereon, will be of chemical and hygienic interest during the visit of the British Association to Bradford.

In the first place these British normal chlorine figures are very high in comparison with the published American data. The lowest Massachusetts figure is ·07 part of Cl per 100,000 in the area farthest removed from the Atlantic sea-border: here the lowest found has been ·7 part per 100,000 in the upper reaches of the Wharf, and all round it appears that the Yorkshire figures are about ten times larger than those of the State of Massachusetts, which is to be accounted for—(1) by the closeness of the sea-border on either side to the Pennine range, and (2) by the density of population in and the antiquity of the inhabited areas.

The unit isochlor area is coextensive with the highest hills and their becks, deans and gills. The following chlorine determinations with waters from the

[1] W. P. Mason, *Examination of Water*, p. 29.

upper reaches of the Wharf, Wenning, Ribble, Aire, and Calder will be sufficiently illustrative:—

	Chlorine parts per 100,000		Chlorine parts per 100,000
Barden	1·0	Ingleborough Cave	1·2
Grimwith Beck	1·2	Lower Bentham	1·4
Gate-up-Gill	0·7	Malham Tarn outlet	1·0
Bleabeck	1·0	„ Cove	0·95
Buckden Pike	1·0	Airehead	1·0
Starbottom	0·8	Old Smelt Mill	1·1
Kettlewell	1·0	Gordale Beck	1·2
Buckden Village	1·2	Hanlith Bridge	1·1
Gaping Ghyll	1·2	Hardcastle Craggs	1·1
Beck Head, Clapdale	1·3	Walshaw Dean	1·1

As the sea is approached, and more populous districts are reached, the chlorine rises, and remarkable examples of rise may be met with on the same hill slope. Halifax furnishes a striking instance. The town rests on a sloping bed of Millstone grit, the ancient and most thickly populated part being towards the bottom of the incline. The ground waters of the highest parts—Mount Tabor—vary from 1·6 to 2·6; widely separated wells, about halfway down, yield the figure 3·8; while towards the bottom of the slope two wells give the figures 4·7 and 5·5. The public water supply from Pennine gathering grounds, ten miles away, stands at 1·5.

The figures obtained for other parts of the West Riding have not yet been severely collated, and are therefore reserved for a further communication.

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4. *On a limiting Standard of Acidity for Moorland Waters.* *By* William Ackroyd, *F.I.C., Public Analyst for Halifax.*

Many large towns, more especially in the West Riding of Yorkshire, have their public water supplies of moorland origin. The case of Milnes *v.* the Huddersfield Corporation in 1881 gave great prominence to the fact that this class of water may give rise to plumbism. No satisfactory explanation could be given at the time, and it is only during the present decade that it has been clearly understood that the plumbo-solvent action of moorland waters is to be associated with acidity. An idea of the relation is furnished by the following determinations:—

Parts per 100·000.

	Acidity in Equivalent of Sulphuric Acid.		Lead dissolved from ½-inch Piping.
1.	0·29	In 1 hour	·03
2.	0·30	„	·057
3.	0·29	„	·025
4.	1·34	In ¼ hour	·71
5.	1·59	„	·95

The acidity is due to carbonic anhydride and peaty acids, and the total is found by ascertaining the number of c.c. of N/100 alkali required to neutralise 100 c.c. of the water, the result being expressed as sulphuric acid. Phenolphthalein is used as the indicator.

The acidity may be very high as from peaty gathering grounds of small incline, say 1 in 44, or comparatively low in gathering grounds of steep incline, say 1 in 12.[1]

In the former case violent action on lead precludes its use for domestic consumption, and in the latter even a limit must be placed on the degree of acidity allowable. During epidemics of plumbism in the West Riding much diversity of opinion has been expressed on various points connected with the matter which the

[1] Ackroyd, *Journ. Chem. Soc.*, 1899, p. 199.

author cannot discuss here; he contents himself with stating that after some years of experience he has never learnt of the occurrence of any case of plumbism where the acidity of the water has been under the equivalent of 0·5 part of sulphuric acid per 100·000 of water, and this he tentatively proposes as a limiting standard of acidity for potable waters of moorland origin when the acidity is determined in the manner already described with phenolphthalein as indicator.

The average acidity of nine samples of water not above suspicion in this respect was 0·63, ranging from 0·53 to 0·91; while on the other hand sixty-one samples above reproach from neighbourhoods where plumbism has not been known had an average acidity of 0·27, the extremes being 0·20 and 0·41.

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5. *On the Effects of Copper on the Human Body.* *By* THOMAS WHITESIDE HIME, *B.A., M.D.*

The recrudescence of an agitation by some public analysts as to alleged danger to health produced by copper has rendered it desirable to make an investigation into the subject, although it was long since satisfactorily disposed of, from a point of view hitherto scarcely utilised as it deserves, and at the same time to review the general results attained. The examination of the two principal excretions, solid and liquid, by which copper is eliminated from the body, offered a promising means of judging of the effects of the agent, whether merely swallowed or also absorbed. These excretions have therefore been examined during a period of several months, from a number of healthy persons engaged, some for many years, in dealing with copper, either in smelting works or as workers in its alloys, brass, &c., or from healthy persons unconnected with any kind of copper work, who had intentionally swallowed some compound of copper in improperly so-called 'greened' vegetables (they are not rendered 'green' by treatment with copper) or otherwise. Copper was found in relative abundance in the excretions of all of these persons, yet they had enjoyed perfect health, and were unconscious of anything abnormal existing in their excretions. It is excreted slowly, and some weeks may elapse before the whole of the copper-compound ingested is got rid of. That fact, that copper may, after being swallowed, be absorbed into the blood and exist there for months, and no doubt during at least twenty years, without indicating its presence by the slightest interference with health, or indeed in any way whatever, has thus been established beyond question. In one case, a brass-finisher aged thirty-eight, who had been thirty years engaged in brass-work, copper was found on various occasions when sought, during several months. For the last fourteen years this man has never drawn any money from his sick club, and he has had perfect health. The copper exists in the excretions, as it does in coppered vegetables, not as copper, but as an insoluble compound, which when tested directly for copper gives no indication of copper being present in any form. As a fact, no copper is present. It is entirely unjustifiable to speak of copper being a poison because when combined with some other elements poisonous effects may be produced by the compound. Because copper and arsenic combined, forming copper arsenite, which is not copper, is poisonous, a death due to copper arsenite is reported and quoted for sixty years in all the text-books as due to 'poisoning by copper!' As well call iron a poison, because it too, when combined to form a new compound, arseniate of iron, may prove poisonous. Copper exists in a great number of plants, including cereals, mineral waters, wines, shell-fish, fruits, and various kinds of animal flesh. It has been calculated that a man eating good bread, 'coppered' only by nature, would consume in this way alone some 93 grains of copper, corresponding to 366 grains of the sulphate. Thousands of wealthy and educated persons who flock yearly to the health-restoring springs of Wiesbaden, Teplitz, Pyrmont, &c., consume copper in every glass of water they drink, yet their health improves, they return yearly to derive fresh benefit, and are unaware that they are being 'poisoned.' Many trustworthy observers have found copper as a normal constituent in the human body. That the consumption of vegetables which have been treated with copper to preserve their natural green is perfectly harmless has

been proved beyond all doubt, not only by such experiments as that of Galippe, who for fourteen months took copper with his food daily without any ill effect, and the classic experiments of Lehmann and his pupils on themselves for many months; but by the infinitely larger experiments made yearly by thousands of the public who consume copper in some form or other in artificially coppered vegetables, and in their flour, fruit, various kinds of flesh, oysters, crabs, wines, mineral waters, &c. 'coppered' by nature. Not one case of injury to health under such circumstances has ever been brought forward, even in prosecutions for selling 'coppered' peas as being 'injurious to health!' The charge is supported by the allegation 'copper is a poison.' But people who eat 'coppered' vegetables do not consume 'copper.' The chemical compound of copper they swallow is not copper at all, and they are not injured. Even verdigris, so much feared, is not all the dangerous substance alleged. Copper utensils are quite harmless with ordinary cleanliness. The alleged 'poisonings' by food cooked in copper vessels have undoubtedly been mostly, if not all, due to ptomaïne-poisoning. Copper has been known and used longer than any other metal, and in its alloys is the most generally used of all metallic substances. It has been in use from prehistoric times, and its dangers, if they existed, must have been known to the ancient and modern world. Yet the ancients are absolutely silent on the subject, and among moderns only a few, almost entirely analysts, declaim to an incredulous public as to dangers which have not been realised. The alleged fraud in so-called 'greening' of vegetables is purely imaginary. The copper does not 'green' old peas or make them look young. Old yellow peas when 'coppered' still look old and yellow. The quantity of the copper compound present in the amount of artificially treated vegetables which is occasionally eaten at a meal is only a fraction of the corresponding amount of copper sulphate which physicians prescribe to be taken three times a day for weeks and months continuously. Therefore there is no sufficient ground for the prohibition of the sale of 'coppered' vegetables, any more than of the innumerable kinds of fruits, vegetables, shell-fish, cereals, mineral waters, wines, and animal flesh which naturally contain the metal in some form. If the latter drastic arrangement were attempted, absolute and general starvation would be the inevitable result, so widely is the natural presence of copper in articles of food extended.

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6. *Interim Report on the Continuation of the Bibliography of Spectroscopy.*—See Reports, p. 150.

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7. *Report on Preparing a New Series of Wave-length Tables of the Spectra of the Elements.*—See Reports, p. 193.

FRIDAY, SEPTEMBER 7.

The following Papers and Reports were read:—

1. *The Specific Heat of Gases at Temperatures up to* 400° *C.* *By* H. B. Dixon, *F.R.S., and* F. W. Rixon, *B.Sc.*

The authors have found that the specific heat of gases between 15° C. and 400° C. may be directly measured by heating the gas (under pressure) in a thin steel cylinder and dropping it into a water calorimeter. A repetition of the experiment with the steel cylinder empty makes the method a differential one, eliminating most of the experimental error.

The specific heat of CO_2 at constant volume has been thus measured between 15° and 115° C., 192° C., 298° C., and 398° C. The specific heat obtained at 115° agrees closely with that obtained by Joly under nearly similar conditions.

The specific heat of CO_2 is found to rise regularly with the temperature. Variations in the pressure of the gas produce slight variations in the specific heat.

The following values have been obtained by reducing the observed values by means of Joly's formula to the same pressure:—

Initial Temperature	Final Temperature	Specific Heat reduced to Pressure of 100 Atmos.
115°	16°	·2000
118°	17°	·2004
192°	17°·5	·2092
298°	21°	·2884
398°	21°	·3565

The authors propose to determine the specific heat of nitrogen and of argon under the same conditions with the same apparatus.

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2. *Interim Report on the Nature of Alloys.*

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3. *Report on the Chemical Compounds contained in Alloys. By* F. H. NEVILLE, *F.R.S.*—See Reports, p. 131.

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4. *On the Mutual Relations of Iron, Phosphorus, and Carbon when together in Cast Iron and Steel. By* J. E. STEAD.

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5. *The Crystalline Structure of Metals.*[1] *By* J. A. EWING, *F.R.S., Professor of Mechanism and Applied Mechanics in the University of Cambridge; and* WALTER ROSENHAIN, *B.A., St. John's College, Cambridge,* 1851 *Exhibition Commissioner's Research Scholar, University of Melbourne.*

The paper describes the results arrived at by the authors in investigating the effects produced upon the micro-structure of metals by (1) plastic strain, and by (2) exposure of strained metal to moderate temperatures. After describing and illustrating the well-known characteristics of crystalline structure in metals as revealed by the microscope, the authors show that plastic strain is accompanied by the appearance of minute steps on a surface of the metal which had been plane polished before the application of the strain. When viewed under the microscope these steps appear as black lines under normally incident light, but they appear as bright bands when oblique light of suitable incidence is used. Their observations lead the authors to conclude that metals yield under plastic strain by the *slipping* of the component parts of each crystal along definite cleavage or gliding plane. The steps in the surface being a consequence of these slips, the authors have called them 'slip-bands.' Further evidence leads the authors to conclude that plastic strain in metals occurs without loss of crystalline character, the crystals as a whole accommodating themselves to new shapes and positions by the slipping of their elements, with the result that the crystalline structure is preserved even when the material as a whole undergoes much deformation.

The use of slip-bands as a means of microscopic observation is also described and illustrated, more particularly with reference to the occurrence and formation of twin-crystals in copper, gold, nickel, lead, and other metals. Slip-bands are also illustrated in various kinds of iron and steel, nickel, zinc, tin, cadmium, lead, silver, gold, bismuth, and some alloys, the magnifications varying from 40 to 1,000 diameters.

[1] For other accounts of these researches see papers by the same authors, *Proc. Roy. Soc.*, March 16 and May 18, 1899, May 31, 1900, and *Phil. Trans.*, vol. A, 1900, and vol. A, 1901.

The second part of the paper deals with the effects of moderate temperatures (up to 200° C.) on such metals as lead, zinc, tin, and cadmium. The authors have found that when these metals are subjected to a very severe plastic strain the original large crystals are broken up into much smaller ones, without, however, destroying their truly crystalline nature. They have further found that when so treated these metals readily recrystallise. In the case of severely strained lead they have shown that even at the ordinary temperature of a room gradual recrystallisation can be observed in the course of several months, while at higher temperatures the changes are much more rapid. A freshly strained specimen exposed to 200° C. was found to recrystallise in a few minutes. It was also found that severe plastic strain is essential to such recrystallisation, and that minute crystals obtained by chilling the metal in casting are not capable of recrystallisation at such moderate temperatures. Closer observation has shown that this recrystallisation of strained metal takes place by the growth of certain of the minute crystals at the expense of their neighbours; individual crystals have been observed to grow until they were many hundreds of times larger than their neighbours.

The final section of the paper deals with a theory which one of the authors (W. Rosenhain) has advanced as an explanation of these phenomena of annealing. According to this view, which both authors believe to be correct, the metallic impurities present in the metal, and forming with it eutectic alloys, play an essential part in these actions. In the ordinary crystallisation of the metal these eutectics form thin films of intercrystalline cement, and, according to the theory of the authors, the growth of one crystal at the expense of its neighbour occurs by means of solution in and diffusion through the eutectic films of the metal constituting the crystals. Evidence is adduced to show that such diffusion would be greater in one direction than the other, and to support the authors' belief that the action may be electrolytic. As a consequence of this theory the authors were led to make experiments on the cold welding of lead, and they have found that, as the theory would indicate, a weld between clean surfaces of lead is a barrier to crystalline growth, but that such growth readily crosses a weld into which a small amount of a suitable metallic impurity had been introduced. The authors believe that these experiments strongly support their 'solution theory' of annealing.

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6. *On the Electric Conductivity of the Alloys of Iron.* *By* Professor W. F. Barrett, *F.R.S.*

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7. *Some new Chemical Compounds discovered by the Use of the Electric Furnace.* *By* C. S. Bradley.

These chemical compounds, which were discovered and examined by Mr. Charles B. Jacobs, of New York, consist of the alkaline earth silicides of calcium, barium, or strontium; by a secondary step silico-acetylene is obtained.

They have the formula $CaSi_2$, $BaSi_2$, and $SrSi_2$ respectively, and are the silicon analogues of the alkaline earth carbides, while the silico-acetylene is the analogue of acetylene having the formula Si_2H_2 when the carbonates or oxides of the alkaline earths are mixed with silica in the form of ground quartz or sand, in which the relative atomic proportion of the alkaline earth metal to the silicon in the mixture is as 1 is to 2, and sufficient carbon to effect the reduction is added, or, when silicates of the alkaline earth metals in which the atomic relation of the earth metal to the silicon is as 1 to 2, are mixed with sufficient carbon to take up the oxygen of the compounds present, and heated in the electric furnace under conditions substantially like those maintained in the manufacture of alkaline earth carbides, silicides of the alkaline earth metals result.

As an example of the process the following reactions for the formation of barium silicide from the barium compounds are given:—

$$(1)\ BaCO_3 + 2\,SiO_2 + 6C = BaSi_2 + 7\,CO$$
$$(2)\ BaO + 2\,SiO_2 + 5C = BaSi_2 + 5\,CO$$

Calcium and strontium silicides are formed by exactly similar reactions from similar compounds. They are white or bluish-white substances of metallic appearance, and also resemble aluminium silicide and silicon somewhat in appearance.

They possess a distinctly crystalline fracture, showing plate-like crystals very similar to those seen in the fracture of cast zinc, the crystals being, however, somewhat smaller in size.

They oxidise slowly in the air and more rapidly under the influence of heat, yielding silicon dioxide and the oxide of the alkaline earth metals present. Like the carbides they decompose with water, but yield, instead of acetylene, hydrogen in a pure state, which is evolved without explosion, the following being the reaction:—

$$(1)\ CaSi_2 + 6\,H_2O = Ca\,(OH)_2 + 2\,SiO_2 + 10H$$
$$(2)\ BaSi_2 + 6\,H_2O = Ba\,(OH)_2 + 2\,SiO_2 + 10H$$
$$(3)\ SrSi_2 + 6\,H_2O = Sr\,(OH)_2 + 2\,SiO_2 + 10H$$

The calcium compound dissolves slowly in cold water, but more rapidly in hot water; the barium compound decomposes rapidly in both cold and hot water. The strontium compound dissolves more rapidly in water than the calcium, but not so rapidly as the barium compound.

It will be noticed by considering the equations 1, 2 and 3, that all of these compounds evolve large volumes of hydrogen:—

1 lb. $CaSi_2$	producing	·104 lb. or 18·73	cubic	ft.	hydrogen
1 lb. $BaSi_2$	„	·051 lb. or 9·15	„		„
1 lb. $SrSi_2$	„	·069 lb. or 12·36	„		„

at 0° C. and 760 mm.

Calcium silicide, when treated with dilute acids, either the oxy-acids or the hydrogen acids, gives rise to the formation of a new compound which has the formula Si_2H_2 and is therefore the silicon analogue of acetylene C_2H_2 and must be called silico-acetylene since it bears the same relation to silico-methane (silicon hydride) SiH_4 as acetylene bears to methane CH_4. The reaction being

$$CaSi_2 + 2\,HCl = CaCl_2 + Si_2H_2$$

Silico-acetylene is a yellow crystalline compound and differs in properties from the compound SiH_3 which Ogier obtained by sparking SiH_4 which was unstable and exploded when subjected to a shock, Si_2H_2 being stable or non-explosive at ordinary temperatures.

When treated with 20 per cent. solution of caustic soda or potash, Si_2H_2 yields hydrogen according to the following equation:—

$$Si_2H_2 + 4\,NaOH + 2\,H_2O = 2\,Na_2\,SiO_3 + 1\,OH$$

Heated in air this compound Si_2H_2 oxidises rapidly, giving 2 SiO_2 H_2O, and when heated in a closed tube it breaks down into amorphous silicon and free hydrogen. Strontium silicide when treated with a strong acid does not produce silico-acetylene with the same facility, while the barium compound when so treated produces a mixture of gaseous compounds and free hydrogen. These silicides can be produced at low cost where electric power is cheap, are very powerful reducing agents, and we hope will find large use in the dye industries. Some experiments have been tried on molten steel carrying phosphorus and sulphur, and the requisite quantity of silicide of barium or calcium completely removed these impurities as well as all oxygen present.

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8. *Report on the Electrolytic Methods of Quantitative Analysis.*
See Reports, p. 171.

MONDAY, SEPTEMBER 10.

The following Papers and Reports were read:—

1. *Derivatives of Methyl-furfural.* *By* HENRY J. HORSTMAN FENTON, *F.R.S., and* Miss MILDRED GOSTLING, *B.Sc.*

The authors have previously shown that an intense purple colour results when *lævulose, cane sugar, sorbose,* or *inulin* is acted upon by dry hydrogen bromide in ethereal solution. The colour-giving substance was isolated in a crystalline state and was shown to be *bromo-methyl-furfural,* its formation being characteristic of ketohexoses, or substances which yield them on hydrolysis. This substance is now the subject of further investigation, and the following results have so far been obtained.

When acted upon by stannous chloride in acid solution the bromine is easily replaced by hydrogen, and the resulting liquid is identical in every way with ∂ methyl-furfural; so that the reaction affords by far the simplest method for the preparation of the latter substance in a pure state.

The bromo-compound, when dissolved in appropriate solvents, readily reacts with various silver salts, giving rise often to beautifully crystalline compounds; the acetoxy- and benzoxy-derivatives have, for example, been prepared and analysed. By the action of sulphurous acid, these, like the parent compound, yield the remarkable condensation product $C_{11}H_8O_4$, which gives beautiful colour-reactions with caustic alkalis and with aniline. This condensation-product has also been further studied, and the results so far favour the author's original suggestion that it is a dicarbonyl compound.

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2. *A Simple Method for comparing the 'Affinities' of certain Acids.* *By* HENRY J. HORSTMAN FENTON, *F.R.S., and* HUMPHREY OWEN JONES, *B.A., B.Sc.*

In a former communication [1] the authors have described the isolation and properties of free oxalacetic acid, and several interesting reactions of this acid are now being investigated. During a more extended study of the *hydrazone* the following somewhat remarkable behaviour has been observed. Heated with dilute sulphuric acid it is transformed, as was previously shown,[2] into Wislicenus's phenyl-pyrazolon carboxylic acid ($C_{10}H_{10}N_2O_4 = C_{10}H_8N_2O_3 + H_2O$); but in order that this change may be complete it is now found that a certain minimum concentration of the acid is necessary. When heated with pure water an entirely different result is obtained: carbon dioxide is evolved, and the *hydrazone* of *pyruvic acid* separates in the crystalline state—$C_{10}H_{10}N_2O_4 = C_9H_{10}N_2O_2 + CO_2$. If the concentration of the acid falls below this necessary minimum both reactions occur simultaneously, even though the acid is present in excess; with decinormal sulphuric acid, for example, about 26 per cent. undergoes the second change. A preliminary set of observations has been made with the following acids, using decinormal solutions and measuring the evolved carbon dioxide in a specially constructed apparatus—*hydrochloric, nitric, sulphuric, trichloracetic, tartaric, malic, succinic, citric, acetic.* The results obtained indicate that the amounts of carbon dioxide evolved are in the inverse order of the concentration of the hydrogen ions, so that a comparison can be made of the relative 'strengths' or 'affinities' of the acids. The order obtained with the above acids agrees remarkably well with that resulting from the other well-established methods.

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3. *Recent Developments in Stereochemistry.* *By* W. J. POPE.

[1] *Trans. Chem. Soc.*, 77, 1900.
[2] *Loc. cit.*

4. *The Constitution of Camphor.* *By* A. Lapworth, *D.Sc.* See Reports, p. 299.

5. *The Degradation of Camphor.* *By* Julius Bredt.

6. *The Camphor Question.* *By* Professor Ossian Aschan.

7. *Report on Isomeric Naphthalene Derivatives.*—See Reports, p. 297.

8. *Report on Isomorphous Derivatives of Benzene.*—See Reports, p. 167.

9. *Report on the Relations between the Absorption Spectra and Chemical Constitution of Organic Bodies.*—See Reports, p. 151.

10. *Action of Aluminium Powder on some Phenols and Acids.* *By* W. R. Hodgkinson.

11. *On the Direct Preparation of β-Naphthylamine.* *By* Dr. Leonhard Limpach *and* W. R. Hodgkinson.

On nitrating naphthalene in the usual manner there results not only α-nitro, but also an appreciable quantity of the β-derivative, as we have several times proved by obtaining β-naphthylamine.

This note has, of course, a theoretical interest only, as β-naphthylamine can so easily be obtained from β-naphthol by the NH_3 process under pressure.[1]

The nitro-naphthalene obtained by direct nitration of naphthalene is reduced in the usual way, and the naphthylamine converted into the HCl salt. The hydrochloride of α-naphthylamine is comparatively insoluble, whilst the hydrochloride of the β-derivative is very soluble. This allows of an easy fractional crystallisation, the mother liquors containing much of the β-salt. A good method of separation consists in treating these mother liquors with potassium hydrate in excess and steam distilling. The steam distillate, after becoming solid, or nearly so, is dried by pressure between paper or on a pump, and then sublimed. β-Naphthylamine alone sublimes, and can in this manner be obtained quite pure, of melting point 112°, and boiling point 304°. It sublimes in beautiful pearly plates.

The amount of β-naphthylamine generally contained in the crude naphthylamine seems to be about 5 per cent. or under.

We have obtained by this method about a kilog. of pure β-naphthylamine from technical naphthylamine mother liquors.

12. *Interaction of Furfuraldehyde and Caro's Reagent.* *By* C. F. Cross, E. J. Bevan, *and* J. F. Briggs.

In a previous paper[2] it was shown that hydrogen peroxide reacted with furfural to form a monohydroxy-furfuraldehyde as the main product, with simultaneous

[1] Siebermann (*Ann.* 123, 264) also obtained β-naphthylamine direct, but by a somewhat roundabout process.

[2] *Chem. Soc. J.*, 1899, p. 747.

production of the corresponding carboxylic acid in small quantity. The substituting groups appear to occupy the 1, 2 positions in the ring.

The monohydroxy furfural is identified, by its very characteristic relations with phloroglucinol and resorcinol, as a constituent of the lignocelluloses.

Caro's reagent, prepared from potassium persulphate and sulphuric acid, according to the directions of Baeyer and Villiger,[1] reacts under similar conditions in a different manner. In the first place the reaction appears to be quantitative, and when the furfural has taken up O_2 a trace of either reagent in excess persists. The temperature remaining at 15°–20°, and there being no evolution of gas, we may expect to find a product of empirical formula $C_5H_4O_4$, and as the aldehydic group disappears this should be a hydropyromucic acid. From the isolation and analysis of a crystalline methylphenyl-hydrazide we confirm the product as a monocarboxylic acid. On reduction with sodium amalgam an aldehydic product is obtained with the brilliant colour reactions of the monohydroxyfurfurals. Control observations on pyromucic acid proved that this acid is reduced under similar conditions to furfural.

The reactions of this hydroxyfurfural, though similar to those described in our previous paper, are sufficiently differentiated to indicate that we have obtained a second isomeride. Moreover, the corresponding acids are differentiated, the one giving Pb and Ba salts, insoluble in acetic acid; the salts of the new acid are soluble, and, moreover, the acid undergoes hydrolysis with such ease as to make its isolation in the pure state a matter of great difficulty. In the course of the usual processes for isolating the Ba and Ca salts, decomposition occurs, and the crystalline salts isolated are those of a dibasic acid. On boiling the original product in solution at constant volume, formic acid distils continuously and with traces only of other acids. The yield of formic acid amounted in one experiment to 0·7 grm. per 1 grm. of original furfural. All these observations indicate that the original product of oxidation is the acid $C_4H_2O\,.\,(COOH)\,(OH)\;1{\cdot}4$ . . . . A characteristic reaction of this original acid is the production of a yellowish-red precipitate with ferric chloride, similar to that obtained with pyromucic acid.

It is to be noted that the Caro reagent oxidises the constituent of the lignocelluloses, which gives the brilliant colour reactions with phenols characteristic of these natural products, which we know to be a hydroxyfurfural. In this respect the reagent differs from the oxidants ordinarily used for bleaching purposes, *e.g.*, hypochlorites and permanganates.

A quantitative experiment with a typical aldose (dextrose) and the Caro reagent gave a somewhat unexpected, entirely negative result. The cupric reduction (Fehling solution) was unaffected.

The typical ketose lævulose, on the other hand, is slowly oxidised.

All of these matters are under investigation.

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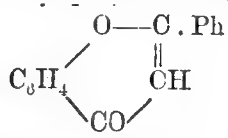
13. *On the Synthesis of Benzo-γ-pyrone.* *By* Dr. S. Ruhemann *and* H. E. Stapleton, *B.A.* (*Oxon.*)

The important group of yellow vegetable dyes, the chief of which are chrysin, fisetin, and morin, are derived primarily from a phenyl benzo-γ-pyrone—



This was synthetised in 1898 by Kostanecki, but the mother substance itself, benzo-γ-pyrone, had not, up to the middle of 1900, been isolated. The authors succeeded in preparing this compound from phenoxy-fumaric acid—

$$\begin{array}{l} COOH\,.\,\underset{|}{C} = CH\,.\,COOH \\ \quad\quad\;\;\; O\,.\,C_6H_5 \end{array}$$

[1] *Ber.*, 1899.

This acid dissolves with evolution of heat in concentrated sulphuric acid, and on diluting the solution with water a new acid is precipitated which was found to be benzo-γ-pyrone carboxylic acid—

$$\begin{array}{l} COOH.\underset{|}{C} = CH\text{—}\underset{|}{CO} \\ \quad\quad\;\; O\;-\;\;\; C_6H_4 \end{array}$$

On distillation *in vacuo* this broke up with the evolution of carbon dioxide, and a liquid distilled over which slowly solidified. It crystallised from a mixture of benzene and ligroin in flat needles which melted at 59°, and analysis showed it to be benzo-γ-pyrone. The yellowish solution of benzo-γ-pyrone in concentrated sulphuric acid possesses a violet fluorescence.

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14. *On the Combination of Thiophenol and Guaiacol with the Esters of the Acids of the Acetylene Series. By* Dr. S. Ruhemann *and* H. E. Stapleton, *B.A.* (*Oxon.*)

In this paper an account is given of the continuation of previous work on the combination of phenols with the esters of the acetylene acids. The authors were induced to study the action of thiophenol on these esters in the hope of finding a new method of preparing thioacetophenone, whilst the investigation of guaiacol was taken up, as no derivative of a dihydric phenol had previously been worked with.

During the progress of the research various new derivatives of thiophenyl-cinnamic, fumaric, and succinic acids were discovered, but it was found that thiophenyl styrene

$$\begin{array}{l} C_6H_5.\underset{|}{C} = CH_2 \\ \quad\quad\;\; S.C_6H_5 \end{array}$$

on boiling with dilute mineral acids is decomposed into acetophenone and hiophenol, and not into thioacetophenone and phenol, as had been expected.

Guaiacol was found to combine readily with phenyl propiolic ester; guaiacolyl cinnamic acid and its ester were prepared, and it was found that the acid on heating quantitatively decomposed into carbon dioxide and guaiacolyl styrene—

$$\begin{array}{l} C_6H_5.\underset{|}{C} = CH_2 \\ \quad\quad\;\; O.C_6H_4\,O.CH_3 \end{array}$$

From the latter mineral acids regenerated guaiacol, with the additional formation of acetophenone.

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15. *Chlorination of Aromatic Hydrocarbons. By* H. D. Dakin *and* J. B. Cohen, *Ph.D.*

TUESDAY, SEPTEMBER 11.

The Section was divided into two Departments.

The following Papers were read:—

Department I.

1. *On some Recent Work on the Diffusion of Gases and Liquids. By* Horace T. Brown, *F.R.S.*

2. *On Recent Developments in the Textile Industries.*
By Dr. A. Liebmann.

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3. *Influence of Pressure on the Formation of Oceanic Salt Deposits.*
By H. M. Dawson, *Ph.D.*, *B.Sc.*

The present paper forms one of a series of investigations carried out with a view of obtaining information in regard to the conditions of formation of the Stassfurt deposits.

In previous papers (van 't Hoff and pupils) the isothermal equilibrium relationships of salts occurring in sea-water and the influence of temperature on these has been investigated. This paper deals with the influence of pressure.

One of the last phases of salt deposition in the Stassfurt layer is represented by tachhydrite ($CaCl_2$ $2MgCl_2$ $12H_2O$); experiment shows that this separates from solutions of the mixed chloride of Ca and Mg if the temperature exceeds 22°·4 C.

Below 22°·4 C. a mixture of the simple salts separates, but no tachhydrite. If the mixed chlorides be heated in the solid condition, then at 22°·4 C. water is split off and tachhydrite is formed.

The influence of pressure on the temperature of formation of this double salt has been studied.

Careful determinations by the thermometric method show that under atmospheric pressure this temperature is 22°·400 C.

By means of the manokryometer the temperature of formation under higher pressures was determined.

The mean result of this direct determination of the influence of pressure is that for an increase of 100 atmospheres the temperature of formation is raised 1°·62 C.

Another and indirect determination is possible by applying the formula of Thomson for the influence of pressure on the melting point to the transition temperature at which calcium chloride, magnesium chloride, tachhydrite, and saturated solution are in equilibrium. From the formula in question, viz.,

$$\frac{dT}{dp} = \frac{1033 \cdot 3\ (v_2 - v_1)}{42500\ q},$$

the determination of $\frac{dT}{dp}$ only involves the knowledge of the change of volume and the heat change accompanying the reaction, which takes place according to

$$\underbrace{CMgCl_2 6H_2O + 1 \cdot 188 CaCl_2 6H_2O}_{v_1}$$

$$\rightleftarrows \underbrace{\cdot 252 CaCl_2 2MgCl_2 \cdot 12H_2O + \cdot 101 \overset{\text{Saturated Solution.}}{(100H_2O\ 9 \cdot 27\ CaCl_2\ 4 \cdot 92\ MgCl_2)}}_{v_2} + q \text{ Cals.}$$

The estimation of $(v_2 - v_1)$ and of q from a series of experiments and substitution in the thermodynamic formula gives for $\frac{dT}{dp}$ the value ·0135° C. In other words, 100 atmospheres would raise the temperature of formation 1°·35 C.

Both results show that the influence of pressure on the separation of salts from solution is very small in comparison with the influence of temperature.

On thermodynamic grounds it can be shown that the influence of pressure on temperature displacement in the case of other salts must be of the same order of magnitude as that found in the case of tachhydrite.

The fact that certain Stassfurt salts (*e.g.*, Kieserte, Kainite, Löwëite and Langbeinite) are not deposited on evaporation of sea-water at a constant

temperature of 25° C. cannot be attributed to the influence of the pressure which has existed during the natural salt deposition, but must be accounted for by the prevalence of higher temperatures. The presence of these salts in the Stassfurt layer enables us, in fact, to draw conclusions in regard to the temperatures which existed during the salt deposition.

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4. *On the Sensitiveness of Metallic Silver to Light.* *By* Major-General J. WATERHOUSE, *I.S.C.*

The paper is a continuation of that read before the Royal Society on May 31, and contains an account of further experiments on the production of visible photographic images upon plain silver surfaces by the action of solar radiations.

The author has found that such visible images are formed when pure silver foils or silvered glass are exposed to sunlight in exhausted glass tubes, and, apparently, more readily in the presence of watery vapour. Invisible, but developable, images were readily obtained in exhausted tubes in which no signs of the presence of moisture were apparent. By prolonged exposure a visible change also takes place.

When *thin* films of silver on glass have been fully exposed in sunlight the action has been found to penetrate the film and produce a distinctly visible image at the back as well as on the face, the exposed parts appearing always lighter than the unexposed.

Fresh experiments with silver plates used as anode and cathode in a decomposition cell containing distilled water, through which a weak current was allowed to pass, showed that the pale grey deposit on the cathode and the dark olive yellow coating on the anode were both quite sensitive to light, and appeared lighter by exposure, in a manner somewhat analogous to that observed on silvered glass or plain silver foils exposed to light.

It was noticed that the visible images were not dissolved away either by the usual photographic fixing agents or by dilute nitric acid.

A very curious action of light upon glass has also been observed. In this case a silvered glass plate was exposed for about a month under a cut-out screen of thin aluminium, the unsilvered side of the glass being in contact with the aluminium and not protected from the air by a covering glass plate. After exposure the plate was put aside for a few days with the exposed glass side in contact with the silvered surface of another piece of polished silvered glass, which was then found to have received an impressed image from the glass of the design cut out of the aluminium screen. The image was quite visible, clear and sharp, and somewhat similar to the images directly impressed by light, though it had not the same appearance of being bleached out, when examined by reflected light. Several days afterwards a second similar image was produced in the same way by contact with the glass upon another freshly polished silvered glass plate, and no doubt several more could be produced in the same way.

These new experiments seem to show that the images formed by the action of light upon plain silver surfaces are due more to molecular or physical changes than to chemical decomposition, though the latter may also probably come into play in the presence of watery vapour, or other conditions favouring oxidation and reduction of the metallic surface. The author is continuing the investigation.

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5. *Some Thoughts on Atomic Weights and the Periodic Law.* *By* J. H. GLADSTONE, *D.Sc., F.R.S., and* GEORGE GLADSTONE.

The object of this paper was to recall attention to a suggestion made during the discussion of a paper by Professor Dumas at the meeting of the Association at Ipswich in 1851, viz., that the case of 'triads' of analogous elements showed a resemblance to the progression in a series of organic compounds, and might be due to a similar cause. It was shown that the difference in atomic weight between the horizontal lines in Mendeljeff's arrangement is in the first instance 16, which afterwards

changes to about 20, and ultimately to about 24. But this increment is really arrived at by 8 steps, giving in the first instance an average of 2·0 for each element; in point of fact, however, the increments are not regular, being for the first line, and starting with lithium, 2·1, 1·9, 1·0, 2·0, 2·0, 3·0, and then 4·0 for two steps, the intermediate one being unknown. This departure from regularity in the increment seems to show that it is of a compound nature; that the original substance may run through the whole series, but be modified by small quantities of one or more additional substances. This would seem to explain not only the slight irregularities, but how our place in Mendeljeff's arrangement may be occupied by two or more elements which closely resemble one another, but differ very slightly in atomic weight or in other properties, such as the iron group, the platinum group, the two didymiums, and the metals associated with yttrium. On this supposition the elements having high atomic weights may be expected to be less regular than is the case in the earlier part of the series.

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6. *The Heating and Lighting Power of Coal Gas.* *By* T. Fairley, *F.R.S.E., F.I.C.*

The author pointed out the importance of knowing the heating power of gas as well as the lighting power, now that it is so largely used for heating and engine purposes.

Coal gas is a complex mixture consisting chiefly of marsh gas and hydrogen with small quantities of heavy hydrocarbons, oxides of carbon, aqueous vapour, nitrogen, &c. The first two control mainly the heating value, and the heavy hydrocarbons the lighting value in ordinary burners. Incandescent gas-burners are not considered in this paper.

That heavy hydrocarbon vapours raise the lighting more than the heating power, explains why carburetted water-gas has a less heating value than ordinary coal-gas of the same lighting power. Air or nitrogen drawn into gas lowers the lighting power more than the heating power.

In gas made from one kind of coal the calorimeter may be worked constantly so as to watch the gas in place of the jet photometer.

The author referred to the various calorimeters invented, and gave directions for securing accuracy. Finally he gave a table of average results showing the heating power of gas of different lighting power.

Lighting power, Standard candles.	Heating power. Pounds of water heated 1° F. by 1 cubic foot of gas.	Lighting power, Standard candles.	Heating Power. Pounds of water heated 1° F. by 1 cubic foot of gas.
11	533	15	624
12	555	16	648
13	578	17	676
14	601	18	704

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7. *On Smoke.* *By* J. B. Cohen, *Ph.D.*

Department II.

1. *Bradford Sewage and its Treatment.* *By* F. W. Richardson, *F.I.C., the Bradford City Analyst.*

In times of normal trade over twenty tons of wool-grease come every weekday into the city's sewers. Wool-suds and effluents, in addition to grease, contain enormous amounts of nitrogenous impurities; thus it is that Bradford sewage is one of the very worst sewages in the kingdom. Of the daily dry-weather flow of twelve million gallons of sewage one and a quarter millions consist of woolcombers

suds and effluents and two millions of dyeworks effluents, with over half a million gallons from Messrs. Lister's, of Manningham Mills. From experiments upon bulks of 20,000 gallons, a mixture of one part of wool-suds and seven parts of Bradford Sunday sewage requires nine times as much precipitant, and produces ten times as much wet and twelve and a half times as much settled sludge, as the Sunday sewage alone. A number of the woolcombers recover part of the wool-grease by 'cracking' the crude suds with oil of vitriol. The effluent so obtained is very acid, contains from 100 to 200 grains of grease per gallon, with a very large amount of nitrogenous impurities. The difficulties arising from the presence of the wool-suds and effluents are twofold: (1) The peculiar emulsive character of wool-grease; (2) the excessive amount of nitrogenous impurities. With Bradford sewage have been tried:—

(1) Lime, giving a clear but bad effluent with a large amount of sludge.

(2) Copperas, followed by lime, producing a turbid but better effluent.

(3) Alumina-ferric, *i.e.*, alumina sulphate, giving unsatisfactory results at a high cost.

(4) Acid ferric sulphate, giving a high degree of purification, but with an acid effluent.

(5) Neutral ferric sulphate, yielding as good results, but with less acidity.

(6) Basic ferric sulphate, giving a 62 per cent. purification and a neutral or slightly alkaline effluent.[1]

The basic sulphate is made at the sewage works by McCulloch's Patent. As it is necessary to use a considerable weight of the basic salt, the method proves costly.

The author has fully investigated the biology of Bradford sewage, and has tried different methods of bacterial treatment. It has not been very difficult to get nitrification with as high a purification in extreme cases as 70 per cent.

The grease present to the extent of 40 to 50 grains per gallon very soon chokes up the filters. There can be no doubt that if the woolcombers' suds and effluents were entirely removed the whole of the city's sewage could be treated biologically, with an immense saving in the cost of chemicals and the treatment of the sludge. Failing the elimination of the wool-suds the best method would seem to be a preliminary treatment with the cheapest precipitant obtainable and the biological purification of the effluent, either on bacteria beds or on land, preferably on both.

Several patentees have experimented on Bradford sewage, but hitherto with unsatisfactory results, and they have all retired from the attempt, saying that the grease baffled them.

After describing the chemical and biological methods in detail, the author entered at some length into the scientific causes of the difficulties of treatment.

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2. *On the Treatment of Woolcombers' Effluents. By* W. Leach.

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3. *On a Simple and Accurate Method for estimating the Dissolved Oxygen in Fresh Water, Sea Water, Sewage Effluents, &c. By* Professor Letts, *D.Sc., Ph.D., &c., and* R. F. Blake, *F.I.C., F.C.S., Queen's College, Belfast.*

After criticising the existing methods for determining the dissolved oxygen in water volumetrically, the authors describe a very simple and accurate method for the purpose, of which the following is an outline:

An ordinary separating funnel is filled with the water to be examined, and a measured volume withdrawn. A definite volume of standard ferrous sulphate solution is then added, and afterwards ammonia—the volume of these two reagents

[1] This effluent, after passing at a rapid rate through fine breeze beds, gives an additional 9 per cent. of purification, although no nitrification occurs.

together corresponding with that of the water removed—and the stopper of the funnel is then inserted, care being taken that no air bubbles are enclosed.

Within the separating funnel there is now a layer of ferrous sulphate below, next the water, and above all the ammonia. These are mixed by inverting the vessel once or twice by a swinging motion, when a greenish turbid mixture results, which rapidly darkens as the dissolved oxygen is absorbed. After fifteen minutes the vessel (still stoppered) is inverted, and its tube or lower extremity (now, however, the upper one) is nearly filled with a mixture of equal volumes of sulphuric acid and water. The tap is then opened, when the acid flows downwards into the alkaline mixture, and in the course of a few minutes dissolves the iron hydrates, forming a clear solution. This is then run off into a porcelain dish, and there titrated, either with permanganate or bichromate, conveniently of the strength 1 c.c. = 1 c.c. of dissolved oxygen at N.T.P.

In the authors' experiment the separating funnel had a capacity of 332·5 c.c., practically $\frac{1}{3}$ litre; and its tube contained, when nearly full, about 8 c.c. of diluted sulphuric acid. About 7 c.c. of the water was removed, 5 c.c. of standard ferrous sulphate solution added and about 2 c.c. of strong ammonia. The ferrous sulphate solution contained about 12 grams of the crystallised salt in 250 c.c. of distilled water. It was standardised for each determination by titrating 5 c.c. in a porcelain basin, mixed with the same volume of the water under examination as employed in the dissolved oxygen determination and the same volume of acid.

For all practical purposes the dissolved oxygen contained in the volume of water which the separating funnel holds amounts to the difference between the burette readings for the blank experiment and for the actual determination. The following are a few typical results:—

Liquid Analysed	Titrations made with	Dissolved Oxygen per litre of fluid		Difference
		Found	True Amount	
Distilled water saturated with air at 13°·7.	Permanganate	7·26	7·20 (Roscoe and Lunt).	+0·06
Belfast water — Town supply.	,,	5·80	5·75 (Gasometric analysis).	+0·05
Seawater from Belfast Lough.	,,	5·53	5·10 (Gasometric analysis).	+0·43
Seawater from Belfast Lough.	Bichromate	5·10		0·00
Sewage effluent from 'Bacteria Beds.'	Permanganate	0·66	0·36 (Gasometric analysis).	+0·30
Sewage effluent from 'Bacteria Beds.'	Bichromate	0·42		+0·06

It will be seen that for sea water and sewage effluents bichromate gives more accurate results than permanganate.

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4. *The Utilisation of Sewage Sludge. By* Professor W. B. Bottomley, *M.A., Ph.D., King's College, London.*

No one system of sewage treatment is universally applicable. Local conditions must determine which system is best for any locality. Parliamentary returns in 1894 gave 233 sanitary districts in England and Wales where systems for treating sewage by precipitation were in operation. In most cases the sludge was not only valueless, but a nuisance.

The author experimented with specially prepared sewage sludge, enriched by the use of phosphatic material in treating the sewage. A crude phosphatic rock was treated with sulphuric acid slightly in excess of the amount necessary to combine with the oxides of iron and aluminium present; the resultant substance

—spoken of as *Phosalite*—was used as a precipitating agent for sewage, and as a pressing agent for sewage sludge.

Experiments at Chiswick Sewage Works, where *Phosalite* was used as a precipitating agent, yielded in the dried sludge cake:—

Nitrogen = Ammonia . . 1·44 Phosphate of Lime . . 6·21

When used as a pressing agent in conjunction with half the usual amount of lime, the dried sludge cake yielded:—

Nitrogen = Ammonia . . 1·94 Phosphate of Lime . . 12·06

Experiments at Glasgow Sewage Works with *Phosalite* as a pressing agent gave the following results:—

a. Sludge pressed with $\frac{1}{2}$ per cent. of lime and 1 per cent. of *Phosalite*:—

Nitrogen = Ammonia . . 1·74 Phosphate of Lime . . 5·72

b. Sludge pressed with $\frac{1}{2}$ per cent. of lime and 2 per cent. of *Phosalite*:—

Nitrogen = Ammonia . . 2·04 Phosphate of Lime . . 9·49

By the use of *Phosalite* as a pressing agent for sludge there was obtained—(*a*) an economy of lime necessary for pressing; (*b*) a much-improved press liquor; (*c*) a greatly enhanced manurial value for the sludge.

These specially enriched sludges, when dried and ground, formed excellent manures, giving results equal to those produced by many high-priced artificial manures. The experiments show that for the effective utilisation of sewage sludge as a manure there are two requisites:—

1. The use of some such phosphatic material as *Phosalite* when pressing the sludge.

2. The resultant sludge-cake must then be dried and ground, so that it may easily mix with the soil.

Section C.—GEOLOGY.

President of the Section—Professor W. J. Sollas, D.Sc., LL.D., F.R.S.

THURSDAY, SEPTEMBER 6.

The President delivered the following Address:—

Evolutional Geology.

The close of one century, the dawn of another, may naturally suggest some brief retrospective glance over the path along which our science has advanced, and some general survey of its present position from which we may gather hope of its future progress; but other connection with geology the beginnings and endings of centuries have none. The great periods of movement have hitherto begun, as it were, in the early twilight hours, long before the dawn. Thus the first step forward, since which there has been no retreat, was taken by Steno in the year 1669; more than a century elapsed before James Hutton (1785) gave fresh energy and better direction to the faltering steps of the young science; while it was less than a century later (1863) when Lord Kelvin brought to its aid the powers of the higher mathematics and instructed it in the teachings of modern physics. From Steno onward the spirit of geology was catastrophic; from Hutton onward it grew increasingly uniformitarian; from the time of Darwin and Kelvin it has become evolutional. The ambiguity of the word 'uniformitarian' has led to a good deal of fruitless logomachy, against which it may be as well at once to guard by indicating the sense in which it is used here In one way we are all uniformitarians, *i.e.*, we accept the doctrine of the 'uniform action of natural causes,' but, as applied to geology, uniformity means more than this. Defined in the briefest fashion it is the geology of Lyell. Hutton had given us a 'Theory of the Earth,' in its main outlines still faithful and true; and this Lyell spent his life in illustrating and advocating; but as so commonly happens the zeal of the disciple outran the wisdom of the master, and mere opinions were insisted on as necessary dogma. What did it matter if Hutton as a result of his inquiries into terrestrial history had declared that he found no vestige of a beginning, no prospect of an end? It would have been marvellous if he had! Consider that when Hutton's 'Theory' was published William Smith's famous discovery had not been made, and that nothing was then known of the orderly succession of forms of life, which it is one of the triumphs of geology to have revealed; consider, too, the existing state of physics at the time, and that the modern theories of energy had still to be formulated; consider also that spectroscopy had not yet lent its aid to astronomy and the consequent ignorance of the nature of nebulæ; and then, if you will, cast a stone at Hutton. With Lyell, however, the case was different: in pressing his uniformitarian creed upon geology he omitted to take into account the great

advances made by its sister sciences, although he had knowledge of them, and thus sinned against the light. In the last edition of the famous 'Principles' we read: 'It is a favourite dogma of some physicists that not only the earth, but the sun itself, is continually losing a portion of its heat, and that as there is no known source by which it can be restored we can foresee the time when all life will cease to exist on this planet, and on the other hand we can look back to a period when the heat was so intense as to be incompatible with the existence of any organic beings such as are known to us in the living or fossil world. . . . A geologist in search of some renovating power by which the amount of heat may be made to continue unimpaired for millions of years, past and future, in the solid parts of the earth . . . has been compared by an eminent physicist to one who dreams he can discover a source of perpetual motion and invent a clock with a self-winding apparatus. *But why should we despair of detecting proofs of such regenerating and self-sustaining power in the works of a Divine Artificer?*' Here we catch the true spirit of uniformity; it admittedly regards the universe as a self-winding clock, and barely conceals a conviction that the clock was warranted to keep true Greenwich time. The law of the dissipation of energy is not a dogma, but a doctrine drawn from observation, while the uniformity of Lyell is in no sense an induction: it is a dogma in the narrowest sense of the word, unproved, incapable of proof; hence perhaps its power upon the human mind; hence also the transitoriness of that power. Again, it is only by restricting its inquiries to the stratified rocks of our planet that the dogma of uniformity can be maintained with any pretence of argument. Directly we begin to search the heavens the possibility, nay even the likelihood, of the nebular origin of our system, with all that it involves, is borne in upon us. Lyell therefore consistently refused to extend his gaze beyond the rocks beneath his feet, and was thus led to do a serious injury to our science: he severed it from cosmogony, for which he entertained and expressed the most profound contempt, and from the mutilation thus inflicted geology is only at length making a slow and painful recovery. Why do I dwell on these facts? To depreciate Lyell? By no means. No one is more conscious than I of the noble service which Lyell rendered to our cause: his reputation is of too robust a kind to suffer from my unskilful handling, and the fame of his solid contributions to science will endure long after these controversies are forgotten. The echoes of the combat are already dying away, and uniformitarians, in the sense already defined, are now no more; indeed, were I to attempt to exhibit any distinguished living geologist as a still surviving supporter of the narrow Lyellian creed, he would probably feel, if such a one there be, that I was unfairly singling him out for unmerited obloquy.

Our science has become evolutional, and in the transformation has grown more comprehensive: her petty parochial days are done, she is drawing her provinces closer around her, and is fusing them together into a united and single commonwealth—the science of the earth.

Not merely the earth's crust, but the whole of earth-knowledge is the subject of our research. To know all that can be known about our planet, this, and nothing less than this, is its aim and scope. From the morphological side geology inquires not only into the existing form and structure of the earth, but also into the series of successive morphological states through which it has passed in a long and changeful development. Our science inquires also into the distribution of the earth in time and space; on the physiological side it studies the movements and activities of our planet; and not content with all this it extends its researches into ætiology and endeavours to arrive at a science of causation. In these pursuits geology calls all the other sciences to her aid. In our commonwealth there are no outlanders; if an eminent physicist enter our territory we do not begin at once to prepare for war, because the very fact of his undertaking a geological inquiry of itself confers upon him all the duties and privileges of citizenship. A physicist studying geology is by definition a geologist. Our only regret is, not that physicists occasionally invade our borders, but that they do not visit us oftener and make closer acquaintance with us.

Early History of the Earth: First Critical Period.

If I am bold enough to assert that cosmogony is no longer alien to geology, I may proceed further, and taking advantage of my temerity pass on to speak of things once not permitted to us. I propose therefore to offer some short account of the early stages in the history of the earth. Into its nebular origin we need not inquire—that is a subject for astronomers. We are content to accept the infant earth from their hands as a molten globe ready made, its birth from a gaseous nebula duly certified. If we ask, as a matter of curiosity, what was the origin of the nebula, I fear even astronomers cannot tell us. There is an hypothesis which refers it to the clashing of meteorites, but in the form in which this is usually presented it does not help us much. Such meteorites as have been observed to penetrate our atmosphere and to fall on to the surface of the earth prove on examination to have had an eventful history of their own of which not the least important chapter was a passage through a molten state; they would thus appear to be the products rather than the progenitors of a nebula.

We commence our history then with a rapidly rotating molten planet, not impossibly already solidified about the centre and surrounded by an atmosphere of great depth the larger part of which was contributed by the water of our present oceans, then existing in a state of gas. This atmosphere, which exerted a pressure of something like 5,000 lb. to the square inch, must have played a very important part in the evolution of our planet. The molten exterior absorbed it to an extent which depended on the pressure, and which may some day be learnt from experiment. Under the influence of the rapid rotation of the earth the atmosphere would be much deeper in equatorial than polar regions, so that in the latter the loss of heat by radiation would be in excess. This might of itself lead to convectional currents in the molten ocean. The effect on the atmosphere is very difficult to trace, but it is obvious that if a high-pressure area originated over some cooler region of the ocean, the winds blowing out of it would drive before them the cooler superficial layers of molten material, and as these were replaced by hotter lava streaming from below, the tendency would be to convert the high into a low pressure area, and to reverse the direction of the winds. Conversely under a low-pressure area the in-blowing winds would drive in the cooler superficial layers of molten matter that had been swept away from the anticyclones. If the difference in pressure under the cyclonic and anticyclonic areas were considerable, some of the gas absorbed under the anticyclones might escape beneath the cyclones, and in a later stage of cooling might give rise to vast floating islands of scoria. Such islands might be the first foreshadowings of the future continents. Whatever the ultimate effect of the reaction of the winds on the currents of the molten ocean, it is probable that some kind of circulation was set up in the latter. The universal molten ocean was by no means homogeneous: it was constantly undergoing changes in composition as it reacted chemically with the internal metallic nucleus: its currents would streak the different portions out in directions which in the northern hemisphere would run from N.E. to S.W., and thus the differences which distinguish particular petrological regions of our planet may have commenced their existence at a very early stage. Is it possible that as our knowledge extends we shall be able by a study of the distribution of igneous rocks and minerals to draw some conclusions as to the direction of these hypothetical lava currents? Our planet was profoundly disturbed by tides, produced by the sun; for as yet there was no moon; and it has been suggested that one of its tidal waves rose to a height so great as to sever its connection with the earth and to fly off as the infant moon. This event may be regarded as marking the first critical period, or catastrophe if we please, in the history of our planet. The career of our satellite, after its escape from the earth, is not known till it attained a distance of nine terrestrial radii; after this its progress can be clearly followed. At the eventful time of parturition the earth was rotating, with a period of from two to four hours, about an axis inclined at some 11° or 12° to the ecliptic. The time which has elapsed

since the moon occupied a position nine terrestrial radii distant from the earth is at least fifty-six to fifty-seven millions of years, but may have been much more. Professor Darwin's story of the moon is certainly one of the most beautiful contributions ever made by astronomy to geology, and we shall all concur with him when he says, 'A theory reposing on *veræ causæ*, which brings into quantitative correlation the length of the present day and month, the obliquity of the ecliptic, and the inclination and eccentricity of the lunar orbit, must, I think, have strong claims to acceptance.'

The majority of geologists have long hankered after a metallic nucleus for the earth, composed chiefly, by analogy with meteorites, of iron. Lord Kelvin has admitted the probable existence of some such nucleus, and lately Professor Wiechert has furnished us with arguments—'powerful' arguments Professor Darwin terms them—in support of its existence. The interior of the earth for four fifths of the radius is composed, according to Professor Wiechert, chiefly of metallic iron, with a density of 8·2; the outer envelope, one fifth of the radius, or about 400 miles in thickness, consists of silicates, such as we are familiar with in igneous rocks and meteorites, and possesses a density of 3·2. It was from this outer envelope when molten that the moon was trundled off, twenty-seven miles in depth going to its formation. The density of this material, as we have just seen, is supposed to be 3·2; the density of the moon is 3·39, a close approximation, such difference as exists being completely explicable by the comparatively low temperature of the moon.

The outer envelope of the earth which was drawn off to form the moon was, as we have seen, charged with steam and other gases under a pressure of 5,000 lb. to the square inch; but as the satellite wandered away from the parent planet this pressure continuously diminished. Under these circumstances the moon would become as explosive as a charged bomb, steam would burst forth from numberless volcanoes, and while the face of the moon might thus have acquired its existing features the ejected material might possibly have been shot so far away from its origin as to have acquired an independent orbit. If so we may ask whether it may not be possible that the meteorites, which sometimes descend upon our planet, are but portions of its own envelope returning to it. The facts that the average specific gravity of those meteorites which have been seen to fall is not much above 3·2, and that they have passed through a state of fusion, are consistent with this suggestion.

Second Critical Period. 'Consistentior Status.'

The solidification of the earth probably became completed soon after the birth of the moon. The temperature of its surface at the time of consolidation was about 1170° C., and it was therefore still surrounded by its primitive deep atmosphere of steam and other gases. This was the second critical period in the history of the earth, the stage of the 'consistentior status,' the date of which Lord Kelvin would rather know than that of the Norman Conquest, though he thinks it lies between twenty and forty millions of years ago, probably nearer twenty than forty.

Now that the crust was solid there was less reason why movements of the atmosphere should be unsteady, and definite regions of high and low pressure might have been established. Under the high-pressure areas the surface of the crust would be depressed; correspondingly under the low-pressure areas it would be raised; and thus from the first the surface of the solid earth might be dimpled and embossed.[1]

Third Critical Period. Origin of the Oceans.

The cooling of the earth would continuously progress, till the temperature of the surface fell to 370° C., when that part of the atmosphere which consisted of steam would begin to liquefy; then the dimples on the surface would soon

[1] It would be difficult to discuss with sufficient brevity the probable distribution of these inequalities, but it may be pointed out that the moon is possibly responsible, and that in more ways than one, for much of the existing geographical asymmetry.

become filled with superheated water, and the pools so formed would expand and deepen, till they formed the oceans. This is the third critical stage in the history of the earth, dating, according to Professor Joly, from between eighty and ninety millions of years ago. With the growth of the oceans the distinction between land and sea arose—in what precise manner we may proceed to inquire. If we revert to the period of the 'consistentior status,' when the earth had just solidified, we shall find, according to Lord Kelvin, that the temperature continuously increased from the surface, where it was 1170° C., down to a depth of twenty-five miles, where it was about 1430° C., or 260° C. above the fusion point of the matter forming the crust. That the crust at this depth was not molten but solid is to be explained by the very great pressure to which it was subjected—just so much pressure, indeed, as was required to counteract the influence of the additional 260° C. Thus if we could have reduced the pressure on the crust we should have caused it to liquefy; by restoring the pressure it would resolidify. By the time the earth's surface had cooled down to 370° C. the depth beneath the surface at which the pressure just kept the crust solid would have sunk some slight distance inwards, but not sufficiently to affect our argument.

The average pressure of the primitive atmosphere upon the crust can readily be calculated by supposing the water of the existing oceans to be uniformly distributed over the earth's surface, and then by a simple piece of arithmetic determining its depth: this is found to be 1·718 miles, the average depth of the oceans being taken at 2·393 miles. Thus the average pressure over the earth's surface, immediately before the formation of the oceans, was equivalent to that of a column of water 1·718 miles high on each square inch. Supposing that at its origin the ocean were all 'gathered together into one place,' and 'the dry land appeared,' then the pressure over the ocean floor would be increased from 1·718 miles to 2·393 miles, while that over those portions of the crust that now formed the land would be diminished by 1·718 miles. This difference in pressure would tend to exaggerate those faint depressions which had arisen under the primitive anti-cyclonic areas, and if the just solidified material of the earth's crust were set into a state of flow it might move from under the ocean into the bulgings which were rising to form the land, until static equilibrium were established. Under these circumstances the pressure of the ocean would be just able to maintain a column of rock 0·886 mile in height, or ten twenty-sevenths of its own depth. It could do no more; but in order that the dry land may appear some cause must be found competent either to lower the ocean bed the remaining seventeen twenty-sevenths of its full depth or to raise the continental bulgings to the same extent. Such a cause may, I think, be discovered in a further effect of the reduction in pressure over the continental areas. Previous to the condensation of the ocean these, as we have seen, were subjected to an atmospheric pressure equal to that of a column of water 1·718 miles in height. This pressure was contributory to that which caused the outer twenty-five miles of the earth's crust to become solid; it furnished indeed just about one fortieth of that pressure, or enough to raise the fusion point 6° C. What then might be expected to happen when the continental area was relieved of this load? Plainly a liquefaction and corresponding expansion of the underlying rock.

But we will not go so far as to assert that actual liquefaction would result; all we require for our explanation is a great expansion; and this would probably follow whether the crust were liquefied or not. For there is good reason to suppose that when matter at a temperature above its ordinary fusion point is compelled into the solid state by pressure, its volume is very responsive to changes either of pressure or temperature. The remarkable expansion of liquid carbon dioxide is a case in point: 120 volumes of this fluid at —20° C. become 150 volumes at 33° C.; a temperature just below the critical point. A great change of volume also occurs when the material of igneous rocks passes from the crystalline state to that of glass; in the case of diabase [1] the difference in volume of the rock in the two

[1] C. Barus so names the material on which he experimented; apparently the rock is a fresh dolerite without olivine.

states at ordinary temperatures is 13 per cent. If the relief of pressure over the site of continents were accompanied by volume changes at all approaching this, the additional elevation of seventeen twenty-sevenths required to raise the land to the sea-level would be accounted for.[1] How far down beneath the surface the unloading of the continents would be felt is difficult to say, though the problem is probably not beyond the reach of mathematical analysis; if it affected an outer envelope twenty-five miles in thickness, a linear expansion of 6 per cent. would suffice to explain the origin of ocean basins. If now we refer to the dilatation determined by Carl Barus for rise in temperature in the case of diabase, we find that between 1093° and 1112° C. the increase in volume is 3·3 per cent. As a further factor in deepening the ocean basins may be included the compressive effect of the increase in load over the ocean floor: this increase is equal to the pressure of a column of water 0·675 mile in height, and its effect in raising the fusion point would be 2° C., from which we may gain some kind of idea of the amount of compression it might produce on the yielding interior of the crust. To admit that these views are speculative will be to confess nothing; but they certainly account for a good deal. They not only give us ocean basins, but basins of the kind we want, that is, to use a crude comparison once made by the late Dr. Carpenter, basins of a tea-tray form, having a somewhat flat floor and steeply sloping sides; they also help to explain how it is that the value of gravity is greater over the ocean than over the land.

The ocean when first formed would consist of highly heated water, and this, as is well known, is an energetic chemical reagent when brought into contact with silicates like those which formed the primitive crust. As a result of its action saline solutions and chemical deposits would be formed; the latter, however, would probably be of no great thickness, for the time occupied by the ocean in cooling to a temperature not far removed from the present would probably be included within a few hundreds of years.

The Stratified Series.

The course of events now becomes somewhat obscure, but sooner or later the familiar processes of denudation and the deposition started into activity, and have continued acting uninterruptedly ever since. The total maximum thickness of

[1] Professor Fitzgerald has been kind enough to express part of the preceding explanation in a more precise manner for me. He writes: 'It would require a very nice adjustment of temperatures and pressures to work out in the simple way you state it; but what is really involved is that in a certain state diabase (and everything that changes state with a considerable change of volume) has an enormous isothermal compressibility. Although this is very enormous in the case of bodies which melt suddenly, like ice, it would also involve very great compressibilities in the case of bodies even which melted gradually, if they did so at all quickly, *i.e.*, within a small range of temperature. What you postulate, then, is that at a certain depth diabase is soft enough to be squeezed from under the oceans, and that, being near its melting point, the small relief of pressure is accompanied by an enormous increase in volume which helped to raise the continents. Now that I have written the thing out in my own way it seems very likely. It is, anyway, a suggestion quite worthy of serious consideration, and a process that in some places must almost certainly have been in operation, and maybe is still operative. Looking at it again, I hardly think it is quite likely that there is or could be much squeezing sideways of liquid or other viscous material from under one place to another, because the elastic yielding of the inside of the earth would be much quicker than any flow of this kind. This would only modify your theory, because the diabase that expands so much on the relief of pressure might be that already under the land, and raising up this latter, partly by being pushed up itself by the elastic relief of the inside of the earth and partly by its own enormous expansibility near its melting point. The action would be quite slow, because it would cool itself so much by its expansion that it would have to be warmed up from below, or by tidal earth-squeezing, or by chemical action before it could expand isothermally.'

the sedimentary deposits, so far as I can discover, appears to amount to no less than 50 miles, made up as follows:—

	Feet	
Recent and Pleistocene	4,000	Man.
Pliocene	5,000	Pithecanthropus.
Miocene	9,000	
Oligocene	12,000	
Eocene	12,000	Eutheria.
Cretaceous	14,000	
Jurassic	8,000	
Trias	13,000	Mammals.
Permian	12,000	Reptiles.
Carboniferous	24,000	Amphibia.
Devonian	22,000	Fish.
Silurian	15,000	
Ordovician	17,000	
Cambrian	16,000	Invertebrata.
Keweenawan	50,000	
Penokee	14,000	
Huronian	18,000	

Geologists, impressed with the tardy pace at which sediments appear to be accumulating at the present day, could not contemplate this colossal pile of strata without feeling that it spoke of an almost inconceivably long lapse of time. They were led to compare its duration with the distances which intervene between the heavenly bodies; but while some chose the distance of the nearest fixed star as their unit, others were content to measure the years in terms of miles from the sun.

Evolution of Organisms.

The stratified rocks were eloquent of time, and not to the geologist alone, they appealed with equal force to the biologist. Accepting Darwin's explanation of the origin of species, the present rate at which form flows to form seemed so slow as almost to amount to immutability. How vast then must have been the period during which by slow degrees and innumerable stages the protozoon was transformed into the man! And if we turn to the stratified column, what do we find? Man, it is true, at the summit, the oldest fossiliferous rocks 34 miles lower down, and the fossils they contain already representing most of the great classes of the Invertebrata, including Crustacea and Worms. Thus the evolution of the Vertebrata alone is known to have occupied a period represented by a thickness of 34 miles of sediment. How much greater, then, must have been the interval required for the elaboration of the whole organic world! The human mind, dwelling on such considerations as these, seems at times to have been affected by a sur-excitation of the imagination, and a consequent paralysis of the understanding, which led to a refusal to measure geological time by years at all, or to reckon by anything less than 'eternities.'

Geologic Periods of Time.

After the admirable Address of your President last year it might be thought needless for me to again enter into a consideration of this subject; it has been said, however, that the question of geological time is like the Djin in Arabian tales, and will irrepressibly come up again for discussion, however often it is disposed of. For my part I do not regard the question so despondingly, but rather hope that by persevering effort we may succeed in discovering the talisman by which we may compel the unwilling Djin into our service. How immeasurable would be the advance of our science could we but bring the chief events which it records into some relation with a standard of time!

Before proceeding to the discussion of estimates of time drawn from a study of stratified rocks let us first consider those which have been already suggested by other data. These are as follows:—(1) Time which has elapsed since the

separation of the earth and moon, fifty-six millions of years, minimum estimate by Professor G. H. Darwin. (2) Since the 'consistentior status,' twenty to forty millions (Lord Kelvin). (3) Since the condensation of the oceans, eighty to ninety millions, maximum estimate by Professor J. Joly.

It may be at once observed that these estimates, although independent, are all of the same order of magnitude, and so far confirmatory of each other. Nor are they opposed to conclusions drawn from a study of stratified rocks; thus Sir Archibald Geikie, in his Address to this Section last year, affirmed that, so far as these were concerned, 100 millions of years might suffice for their formation. There is then very little to quarrel about, and our task is reduced to an attempt, by a little stretching and a little paring, to bring these various estimates into closer harmony.

Professor Darwin's estimate is admittedly a minimum; the actual time, as he himself expressly states, 'may have been much longer.' Lord Kelvin's estimate, which he would make nearer twenty than forty millions, is founded on the assumption that since the period of the 'consistentior status' the earth has cooled simply as a solid body, the transference of heat from within outwards having been accomplished solely by conduction.

It may be at once admitted that there is a large amount of truth in this assumption; there can be no possible doubt that the earth reacts towards forces applied for a short time as a solid body. Under the influence of the tides it behaves as though it possessed a rigidity approaching that of steel, and under sudden blows, such as those which give rise to earthquakes, with twice this rigidity, as Professor Milne informs me. Astronomical considerations lead to the conclusion that its effective rigidity has not varied greatly for a long period of past time.

Still, while fully recognising these facts, the geologist knows—we all know—that the crust of the earth is not altogether solid. The existence of volcanoes by itself suggests the contrary, and although the total amount of fluid material which is brought from the interior to the exterior of the earth by volcanic action may be, and certainly is, small—from data given by Professor Penck, I estimate it as equivalent to a layer of rock uniformly distributed 2 mm. thick per century[1]—yet we have every reason to believe that volcanoes are but the superficial manifestation of far greater bodies of molten material which lie concealed beneath the ground. Even the wide areas of plutonic rock, which are sometimes exposed to view over a country that has suffered long-continued denudation, are merely the upper portion of more extensive masses which lie remote from view. The existence of molten material within the earth's crust naturally awakens a suspicion that the process of cooling has not been wholly by conduction, but also to some slight extent by convection, and to a still greater extent by the bodily migration of liquid lava from the deeper layers of the crust towards the surface.

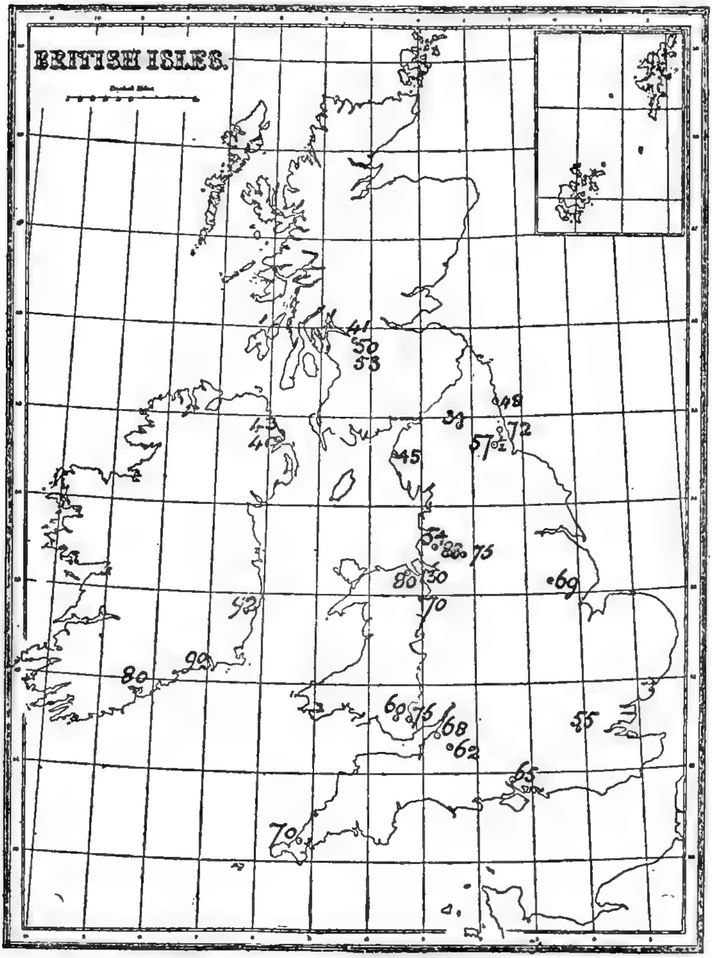
The existence of local reservoirs of molten rock within the crust is even still more important in another connection, that is, in relation with the supposed 'average rate of increase of temperature with descent below the ground.' It is doubtful whether we have yet discovered a rate that in any useful sense can be spoken of as 'average. The widely divergent views of different authorities as to the presumed value of this rate may well lead to reflection. The late Professor Prestwich thought a rise of 1° F. for every 45 feet of descent below the zone of constant temperature best represented the average; Lord Kelvin in his earlier estimates has adopted a value of 1° F. for every 51 feet; the Committee of this Association appointed to investigate this question arrived at a rate of 1° F. for every 60 feet of descent; Mr. Clarence King has made calculations in which a rate of 1° F. for 72 feet is adopted; a re-investigation of recorded measurements would, I believe, lead to a rate of 1° F. in 80 or 90 feet as more closely approaching the mean. This would raise Lord Kelvin's estimate to nearly fifty millions of years.

When from these various averages we turn to the observations on which they are based, we encounter a surprising divergence of extremes from the

[1] The heat thus brought to the surface would amount to one seventeenth of that conveyed by conduction.

mean; thus in the British Isles alone the rate varies from 1° F. in 34 feet to 1° F. in 92 feet, or in one case to 1° F. in 130 feet. It has been suggested, and to some extent shown, that these irregularities may be connected with differences in conductivity of the rocks in which the observations were made, or with the circulation of underground water; but many cases exist which cannot be explained away in such a manner, but are suggestive of some deep-seated cause, such as the distribution of molten matter below the ground. Inspection of the accompanying map of the British Isles, on which the rates of increase in

FIG. 1.—Map of the British Isles, showing the distribution of rates of increase of temperature with descent. The rates are taken from the 'British Association Report,' except in the case of those in the south of Ireland.



different localities have been plotted, will afford some evidence of the truth of this view. Comparatively low rates of increase are found over Wales and in the province of Leinster, districts of relatively great stability, the remnants of an island that have in all probabilty stood above the sea ever since the close of the Silurian period. To the north of this, as we enter a region which was subject to volcanic disturbances during the Tertiary period, the rate increases.

It is obvious that in any attempt to estimate the rate at which the earth is cooling as a solid body the disturbing influence of subterranean lakes of molten rock must as far as possible be eliminated; but this will not be effected by taking

the accepted mean of observed rates of increase of temperature: such an average is merely a compromise, and a nearer approach to a correct result will possibly be attained by selecting some low rate of increase, provided it be based on accurate observations.

It is extremely doubtful whether an area such as the British Isles, which has so frequently been the theatre of volcanic activity and other subterranean disturbance, is the best fitted to afford trustworthy results; the Archæan nucleus of a continent might be expected to afford surer indications. Unfortunately the hidden treasures of the earth are seldom buried in these regions, and bore-holes in consequence have rarely been made in them. One exception is afforded by the copper-bearing district of Lake Superior, and in one case, that of the Calumet and Hecla mine, which is 4,580 feet in depth, the rate of increase, as determined by Professor A. Agassiz, was 1° F. for every 223·7 feet. The Bohemian 'horst' is a somewhat ancient part of Europe, and in the Przibram mines, which are sunk in it, the rate was 1° F. for every 126 feet of descent. In the light of these facts it would seem that geologists are by no means compelled to accept the supposed mean rate of increase of temperature with descent into the crust as affording a safe guide to the rate of cooling of a solid globe; and if the much slower rate of increase observed in the more ancient and more stable regions of the earth has the importance which is suggested for it, then Lord Kelvin's estimate of the date of the 'consistentior status' may be pushed backwards into a remoter past.

If, as we have reason to hope, Lord Kelvin's somewhat contracted period will yield to a little stretching, Professor Joly's, on the other hand, may take some paring. His argument, broadly stated, is as follows. The ocean consisted at first of fresh water; it is now salt, and its saltness is due to the dissolved matter that is constantly being carried into it by rivers. If, then, we know the quantity of salt which the rivers bring down each year into the sea, it is easy to calculate how many years they have taken to supply the sea with all the salt it at present contains. For several reasons it is found necessary to restrict attention to one only of the elements contained in sea salt: this is sodium. The quantity of sodium delivered to the sea every year by rivers is about 160,000,000 tons; but the quantity of sodium which the sea contains is at least ninety millions of times greater than th s. The period during which rivers have been carrying sodium into the sea must therefore be about ninety millions of years. Nothing could be simpler; there is no serious flaw in the method, and Professor Joly's treatment of the subject is admirable in every way; but of course in calculations such as this everything depends on the accuracy of the data, which we may therefore proceed to discuss. Professor Joly's estimate of the amount of sodium in the ocean may be accepted as sufficiently near the truth for all practical purposes. We may therefore pass on to the other factor, the annual contribution of sodium by river water. Here there is more room for error. Two quantities must be ascertained: one the quantity of water which the rivers of the world carry into the sea, the other the quantity or proportion of sodium present in this water. The total volume of water discharged by rivers into the ocean is estimated by Sir John Murray as 6,524 cubic miles. The estimate being based on observations of thirty-three great rivers, although only approximate, it is no doubt sufficiently exact; at all events such alterations as it is likely to undergo will not greatly affect the final result. When, however, we pass to the last quantity to be determined, the chemical composition of average river water, we find that only a very rough estimate is possible, and this is the more unfortunate because changes in this may very materially affect our conclusions. The total quantity of river water discharged into the sea is, as we have stated, 6,524 cubic miles. The average composition of this water is deduced from analyses of nineteen great rivers, which altogether discharge only 488 cubic miles, or 7·25 per cent. of the whole. The danger in using this estimate is two-fold: in the first place 7·25 is too small a fraction from which to argue to the remaining 92·75 per cent., and, next, the rivers which furnish it are selected rivers, *i.e.*, they are all of large size. The effect of this is that the drainage of the volcanic regions of the earth is not sufficiently represented, and it is precisely this drainage which is richest in sodium salts. The lavas and ashes of active volcanoes rapidly

disintegrate under the energetic action of various acid gases, and among volcanic exhalations sodium chloride has been especially noticed as abundant. Consequently we find that while the proportion of sodium in Professor Joly's average river water is only 5·73 per million, in the rivers of the volcanic island of Hawaii it rises to 24·5 per million.[1] No doubt the area occupied by volcanoes is trifling compared with the remaining land surface. On the other hand the majority of volcanoes are situated in regions of copious rainfall, of which they receive a full share owing to their mountainous form. Much of the fallen rain percolates through the porous material of the cone, and, richly charged with alkalies, finds its way by underground passages towards the sea, into which it sometimes discharges by submarine springs.

Again, several considerations lead to the belief that the supply of sodium to the ocean has proceeded, not at a uniform, but at a gradually diminishing rate. The rate of increase of temperature with descent into the crust has continuously diminished with the flow of time, and this must have had its influence on the temperature of springs, which furnish an important contribution to river water. The significance of this consideration may be judged from the composition of the water of geysers. Thus Geyser, in Iceland, contains 884 parts of sodium per million, or nearly 160 times as much as Sir John Murray estimates is present in average river water. A mean of the analyses of six geysers in different parts of the world gives 400 parts of sodium per million, existing partly as chloride, but also as sulphate and carbonate.

It should not be overlooked that the present is a calm and quiet epoch in the earth's history, following after a time of fiery activity. More than once, indeed, has the past been distinguished by unusual manifestations of volcanic energy, and these must have had some effect upon the supply of sodium to the ocean. Finally, although the existing ocean water has apparently but slight effect in corroding the rocks which form its bed, yet it certainly was not inert when its temperature was not far removed from the critical point. Water begins to exert a powerful destructive action on silicates at a temperature of 180° C., and during the interval occupied in cooling, from 370° to 180° C., a considerable quantity of sodium may have entered into solution.

A review of the facts before us seems to render some reduction in Dr. Joly's estimate imperative. A precise assessment is impossible, but I should be inclined myself to take off some ten or thirty millions of years.

We may next take the evidence of the stratified rocks. Their total maximum thickness is, as we have seen, 265,000 feet, and consequently if they accumulated at the rate of one foot in a century, as evidence seems to suggest, more than twenty-six millions of years must have elapsed during their formation.

Obscure Chapter in the Earth's History.

Before discussing the validity of the argument on which this last result depends let us consider how far it harmonises with previous ones. It is consistent with Lord Kelvin's and Professor Darwin's, but how does it accord with Professor Joly's? Supposing we reduce his estimate to fifty-five millions: what was the earth doing during the interval between the period of fifty-five millions of years ago and that of only 26½ millions ago, when, it is presumed, sedimentary rocks commenced to be formed? Hitherto we have been able to reason on probabilities; now we enter the dreary region of possibilities, and open that obscure chapter in the history of the earth previously hinted at. For there are many possible answers to this question. In the first place the evidence of the stratified rocks may have been wrongly interpreted, and two or three times the amount of time we have demanded may have been consumed in their formation. This is a very obvious possibility, yet again our estimate concerning these rocks may be correct, but we may have erroneously omitted to take into account certain portions of the Archæan complex, which may represent primitive sedimentary rocks, formed under exceptional con-

[1] Walter Maxwell, *Lavas and Soils of the Hawaiian Islands*, p. 170.

ditions, and subsequently transformed under the influence of the internal heat of the earth. This, I think, would be Professor Bonney's view. Finally Lord Kelvin has argued that the life of the sun as a luminous star is even more briefly limited than that of our oceans. In such a case if our oceans were formed fifty-five millions of years ago, it is possible that after a short existence as almost boiling water they grew colder and colder, till they became covered with thick ice, and moved only in obedience to the tides. The earth, frozen and dark, except for the red glow of her volcanoes, waited the coming of the sun, and it was not till his growing splendour had banished the long night that the cheerful sound of running waters was heard again in our midst. Then the work of denudation and deposition seriously recommenced, not to cease till the life of the sun is spent. Thus the thickness of the stratified series may be a measure rather of the duration of sunlight than of the period which has elapsed since the first formation of the ocean. It may have been so—we cannot tell—but it may be fairly urged that we know less of the origin, history, and constitution of the sun than of the earth itself, and that, for aught we can say to the contrary, the sun may have been shining on the just-formed ocean as cheerfully as he shines to-day.

Time required for the Evolution of the Living World.

But, it will be asked, how far does a period of twenty-six millions satisfy the demands of biology? Speaking only for myself, although I am aware that eminent biologists are not wanting who share this opinion, I answer, Amply. But it will be exclaimed, Surely there are 'comparisons in things.' Look at Egypt, where more than 4,000 years since the same species of man and animals lived and flourished as to-day. Examine the frescoes and study the living procession of familiar forms they so faithfully portray, and then tell us, how comes it about that from changes so slow as to be inappreciable in the lapse of forty centuries you propose to build up the whole organic world in the course of a mere twenty-six millions of years? To all which we might reply that even changeless Egypt presents us with at least one change—the features of the ruling race are to-day not quite the same as those of the Pharaohs. But putting this on one side, the admitted constancy in some few common forms proves very little, for so long as the environment remains the same natural selection will conserve the type, and, so far as we are able to judge, conditions in Egypt have remained remarkably constant for a long period.

Change the conditions, and the resulting modification of the species becomes manifest enough; and in this connection it is only necessary to recall the remarkable mutations observed and recorded by Professor Weldon in the case of the crabs in Plymouth Harbour. In response to increasing turbidity of the sea water these crabs have undergone or are undergoing a change in the relative dimensions of the carapace, which is persistent, in one direction, and rapid enough to be determined by measurements made at intervals of a few years.

Again, animals do not all change their characters at the same rate: some are stable, in spite of changing conditions, and these have been cited to prove that none of the periods we look upon as probable, not twenty-five, not a hundred millions of years, scarce any period short of eternity, is sufficient to account for the evolution of the living world. If the little tongue-shell, *Lingula*, has endured with next to no perceptible change from the Cambrian down to the present day, how long, it is sometimes inquired, would it require for the evolution of the rest of the animal kingdom? The reply is simple: the cases are dissimilar, and the same record which assures us of the persistency of the *Lingula* tells us in language equally emphatic of the course of evolution which has led from the lower organisms upwards to man. In recent and Pleistocene deposits the relics of man are plentiful: in the latest Pliocene they have disappeared, and we encounter the remarkable form *Pithecanthropus*; as we descend into the Tertiary systems the higher mammals are met with, always sinking lower and lower in the scale of organisation as they occur deeper in the series, till in the Mesozoic deposits they have entirely disappeared, and their place is taken by the lower mammals, a feeble folk, offering little promise of the future they were to inherit. Still lower, and even these are gone; and in the Permian

we encounter reptiles and the ancestors of reptiles, probably ancestors of mammals too; then into the Carboniferous, where we find amphibians, but no true reptiles: and next into the Devonian, where fish predominate, after making their earliest appearance at the close of the Silurian times; thence downwards, and the vertebrata are no more found—we trace the evolution of the invertebrata alone. Thus the orderly procession of organic forms follows in precisely the true phylogenetic sequence: invertebrata first, then vertebrates, at first fish, then amphibia, next reptiles, soon after mammals, of the lowlier kinds first, of the higher later, and these in increasing complexity of structure till we finally arrive at man himself. While the living world was thus unfolding into new and nobler forms, the immutable *Lingula* simply perpetuated its kind. To select it, or other species equally sluggish, as the sole measure of the rate of biologic change would seem as strange a proceeding as to confound the swiftness of a river with the stagnation of the pools that lie beside its banks. It is occasionally objected that the story we have drawn from the palæontological record is mere myth or is founded only on negative evidence. Cavils of this kind prove a double misapprehension, partly as to the facts, partly as to the value of negative evidence, which may be as good in its way as any other kind of evidence.

Geologists are not unaware of the pitfalls which beset negative evidence, and they do not conclude from the absence of fossils in the rocks which underlie the Cambrian that pre-Cambrian periods were devoid of life; on the contrary, they are fully persuaded that the seas of those times were teeming with a rich variety of invertebrate forms. How is it that, with the exception of some few species found in beds immediately underlying the Cambrian, these have left behind no vestige of their existence? The explanation does not lie in the nature of the sediments, which are not unfitted for the preservation of fossils, nor in the composition of the then existing sea water, which may have contained quite as much calcium carbonate as occurs in our present oceans; and the only plausible supposition would appear to be that the organisms of that time had not passed beyond the stage now represented by the larvæ of existing invertebrata, and consequently were either unprovided with skeletons or at all events with skeletons durable enough for preservation. If so, the history of the earlier stages of the evolution of the invertebrata will receive no light from palæontology; and no direct answer can be expected to the question whether, eighteen or nineteen millions of years being taken as sufficient for the evolution of the vertebrata, the remaining available eight millions would provide for that of the invertebrate classes which are represented in the lowest Cambrian deposits. On *à priori* grounds there would appear to be no reason why it should not. If two millions of years afforded time enough for the conversion of fish into amphibians, a similar period should suffice for the evolution of trilobites from annelids, or of annelids from trochospheres. The step from gastrulas to trochospheres might be accomplished in another two millions, and two millions more would take us from gastrulas through morulas to protozoa.

As things stand, biologists can have nothing to say either for or against such a conclusion: they are not at present in a position to offer independent evidence; nor can they hope to be so until they have vastly extended those promising investigations which they are only now beginning to make into the rate of the variation of species.

Unexpected Absence of Thermal Metamorphosis in Ancient Rocks.

Two difficulties now remain for discussion: one based on theories of mountain chains, the other on the unaltered state of some ancient sediments. The latter may be taken first. Professor van Hise writes as follows regarding the pre-Cambrian rocks of the Lake Superior district: 'The Penokee series furnishes an instructive lesson as to the depth to which rocks may be buried and yet remain but slightly affected by metamorphosis. The series itself is 14,000 feet thick. It was covered before being upturned with a great thickness of Keweenaw rock. This series at the Montreal River is estimated to be 50,000 feet thick. Adding to this the known thickness of the Penokee series, we have a thickness of 64,000 feet. . . . The

Penokee rocks were then buried to a great depth, the exact amount depending upon their horizon and upon the stage in Keweenaw time, when the tilting and erosion, which brought them to the surface, commenced.

'That the synclinal trough of Lake Superior began to form before the end of the Keweenaw period, and consequently that the Penokee rocks were not buried under the full succession, is more than probable. However, they must have been buried to a great depth—at least several miles—and thus subjected to high pressure and temperature, notwithstanding which they are comparatively unaltered.' [1]

I select this example because it is one of the best instances of a difficulty that occurs more than once in considering the history of sedimentary rocks. On the supposition that the rate of increment of temperature with descent is 1° F. for every 84 feet, or 1° C. for every 150 feet, and that it was no greater during these early Penokee times, then at a depth of 50,000 feet the Penokee rocks would attain a temperature of nearly 333° C.; and since water begins to exert powerful chemical action at 180° C. they should, on the theory of a solid cooling globe, have suffered a metamorphosis sufficient to obscure their resemblance to sedimentary rocks. Either then the accepted rate of downward increase of temperature is erroneous, or the Penokee rocks were never depressed, in the place where they are exposed to observation, to a depth of 50,000 feet. Let us consider each alternative, and in the first place let us apply the rate of temperature increment determined by Professor Agassiz in this very Lake Superior district: it is 1° C. for every 402 feet, and twenty-five millions of years ago, or about the time when we may suppose the Penokee rocks were being formed, it would be 1° C. for every 305·5 feet, with a resulting temperature at a depth of 50,000 feet of 163° C. only. Thus the admission of a very low rate of temperature increment would meet the difficulty; but on the other hand it would involve a period of several hundreds of millions of years for the age of the 'consistentior status,' and thus greatly exceed Professor Joly's maximum estimate of the age of the oceans. We may therefore turn to the second alternative. As regards this it is by no means certain that the exposed portion of the Penokee series ever was depressed 50,000 feet: the beds lie in a synclinal the base of which indeed may have sunk to this extent, and entered a region of metamorphosis; but the only part of the system that lies exposed to view is the upturned margin of the synclinal, and as to this it would seem impossible to make any positive assertion as to the depth to which it may or may not have been depressed. To keep an open mind on the question seems our only course for the present, but difficulties like this offer a promising field for investigation.

The Formation of Mountain Ranges.

It is frequently alleged that mountain chains cannot be explained on the hypothesis of a solid earth cooling under the conditions and for the period we have supposed. This is a question well worthy of consideration, and we may first endeavour to picture to ourselves the conditions under which mountain chains arise. The floor of the ocean lies at an average depth of 2,000 fathoms below the land, and is maintained at a constant temperature, closely approaching 0° C., by the passage over it of cold water creeping from the polar regions. The average temperature of the surface of the land is above zero, but we can afford to disregard the difference in temperature between it and the ocean floor, and may take them both at zero. Consider next the increase of temperature with descent, which occurs beneath the continents: at a depth of 13,000 feet, or at same depth as the ocean floor, a temperature of 87° C. will be reached on the supposition that the rate of increase is 1° C. for 150 feet, while with the usually accepted rate of 1° C. for 108 feet it would be 120° C. But at this depth the ocean floor, which is on the same spherical surface, is at 0° C. Thus surfaces of equal temperature within the earth's crust will not be spherical, but will rise or fall beneath an imaginary spherical or spheroidal surface according as they occur beneath the continents or the oceans. No doubt at some depth within the earth the departure of isothermal

[1] *Tenth Annual Report U.S. Geol. Survey*, 1888-89, p. 457.

surfaces from a spheroidal form will disappear; but considering the great breadth both of continents and oceans this depth must be considerable, possibly even forty or fifty miles. Thus the sub-continental excess of temperature may make itself felt in regions where the rocks still retain a high temperature, and are probably not far removed from the critical fusion point. The effect will be to render the continents mobile as regards the ocean floor; or, *vice versâ*, the ocean floor will be stable compared with the continental masses. Next it may be observed that the continents pass into the bed of the ocean by a somewhat rapid flexure, and that it is over this area of flexure that the sediments denuded from the land are deposited. Under its load of sediment the sea-floor sinks down, subsiding slowly, at about the same rate as the thickness of sediment increases; and, whether as a consequence or a cause, or both, the flexure marking the boundary of land and sea becomes more pronounced. A compensating movement occurs within the earth's crust, and solid material may flow from under the subsiding area in the direction of least resistance, possibly towards the land. At length, when some thirty or forty thousand feet of sediment have accumulated in a basin-like form, or, according to our reckoning, after the lapse of three or four millions of years, the downward movement ceases, and the mass of sediment is subjected to powerful lateral compression, which, bringing its borders into closer proximity by some ten or thirty miles, causes it to rise in great folds high into the air as a mountain chain.

It is this last phase in the history of mountain making which has given geologists more cause for painful thought than probably any other branch of their subject, not excluding even the age of the earth. It was at first imagined that during the flow of time the interior of the earth lost so much heat, and suffered so much contraction in consequence, that the exterior, in adapting itself to the shrunken body, was compelled to fit it like a wrinkled garment. This theory, indeed, enjoyed a happy existence till it fell into the hands of mathematicians, when it fared very badly, and now lies in a pitiable condition neglected of its friends.[1]

For it seemed proved to demonstration that the contraction consequent on cooling was wholly, even ridiculously, inadequate to explain the wrinkling. But when we summon up courage to inquire into the data on which the mathematical arguments are based, we find that they include several assumptions the truth of which is by no means self-evident. Thus it has been assumed that the rate at which the fusion point rises with increased pressure is constant, and follows the same law as is deduced from experiments made under such pressures as we can command in our laboratories down to the very centre of the earth, where the pressures are of an altogether different order of magnitude; so with a still more important coefficient, that of expansion, our knowledge of this quantity is founded on the behaviour of rocks heated under ordinary atmospheric pressure, and it is assumed that the same coefficient as is thus obtained may be safely applied to material which is kept solid, possibly near the critical point, under the tremendous pressure of the depths of the crust. To this last assumption we owe the terrible bogies that have been conjured out of 'the level of no strain.' The depth of this as calculated by the Rev. O. Fisher is so trifling that it would be passed through by all very deep mines. Mr. C. Davison, however, has shown that it will lie considerably deeper, if the known increase of the coefficient of expansion with rise of temperature be taken into account. It is possible, it is even likely, that the coefficient of expansion becomes vastly greater when regions are entered, where the rocks are compelled into the solid state by pressure. So little do we actually know of the behaviour of rock under these conditions that the geologist would seem to be left very much to his own devices; but it would seem there is one temptation he must resist—he may not take refuge in the hypothesis of a liquid interior.

We shall boldly assume that the contraction at some unknown depth in the interior of the earth is sufficient to afford the explanation we seek. The course of events may then proceed as follows. The contraction of the interior of the earth,

[1] With some exceptions, notably Mr. C. Davison, a consistent supporter of the theory of contraction.

consequent on its loss of heat, causes the crust to fall upon it in folds, which rise over the continents and sink under the oceans, and the flexure of the area of sedimentation is partly a consequence of this folding, partly of overloading. By the time a depression of some 30,000 or 40,000 feet has occurred along the ocean border the relation between continents and oceans has become unstable, and readjustment takes place, probably by a giving way of the continents, and chiefly along the zone of greatest weakness, *i.e.* the area of sedimentation, which thus becomes the zone of mountain building. It may be observed that at great depths readjustment will be produced by a slow flowing of solid rock, and it is only comparatively near the surface, five or ten miles at the most below, that failure of support can lead to sudden fracture and collapse; hence the comparatively superficial origin of earthquakes.

Given a sufficiently large coefficient of expansion—and there is much to suggest its existence [1]—and all the phenomena of mountain ranges become explicable: they begin to present an appearance that invites mathematical treatment; they inspire us with the hope that from a knowledge of the height and dimensions of a continent and its relations to the bordering ocean we may be able to predict when and where a mountain chain should arise, and the theory which explains them promises to guide us to an interpretation of those world-wide unconformities which Suess can only account for by a transgression of the sea. Finally it relieves us of the difficulty presented by mountain formation in regard to the estimated duration of geological time.

Influence of Variations in the Eccentricity of the Earth's Orbit.

This may perhaps be the place to notice a highly interesting speculation which we owe to Professor Blytt, who has attempted to establish a connection between periods of readjustment of the earth's crust and variations in the eccentricity of the earth's orbit. Without entering into any discussion of Professor Blytt's methods, we may offer a comparison of his results with those that follow from our rough estimate of one foot of sediment accumulated in a century.

Table showing the Time that has elapsed since the Beginning of the Systems in the first column, as reckoned from Thickness of Sediment in the second column, and by Professor Blytt in the third:—

—	Years	Years
Eocene	4,200,000	3,250,000
Oligocene	3,000,000	1,810,000
Miocene	1,800,000	1,160,000
Pliocene	900,000	700,000
Pleistocene	400,000	350,000

It is now time to return to the task, too long postponed, of discussing the data from which we have been led to conclude that a probable rate at which sediments have accumulated in places where they attain their maximum thickness is one foot per century.

Rate of Deposition of Sediment.

We owe to Sir Archibald Geikie a most instructive method of estimating the existing rate at which our continents and islands are being washed into the sea by the action of rain and rivers: by this we find that the present land surface is being reduced in height to the extent on an average of $\frac{1}{2400}$ foot yearly.[2] If the material removed from the land were uniformly distributed over an area equal to that from which it had been derived, it would form a layer of rock $\frac{1}{2400}$ foot thick yearly, *i.e.* the rates of denudation and deposition would be identical. But the two areas, that of denudation and that of deposition, are seldom or never equal, the latter

[1] *Vide* p. 715.

[2] According to Professor Penck $\frac{1}{3600}$ foot.

as a rule being much the smaller. Thus the area of that part of North America which drains into the Gulf of Mexico measures 1,800,000 square miles; the area over which its sediments are deposited is, so far as I can gather from Professor Agassiz's statements, less than 180,000 square miles; while Mr. McGee estimates it at only 100,000 square miles. Using the larger number, the area of deposition is found to measure one tenth the area of denudation; the average rate of deposition will therefore be ten times as great as the rate of denudation, or $\frac{1}{240}$ foot may be supposed to be uniformly distributed over the area of sedimentation in the course of a year. But the thickness by which we have measured the strata of our geological systems is not an average but a maximum thickness; we have therefore to obtain an estimate of the maximum rate of deposition. If we assume the deposited sediments to be arranged somewhat after the fashion of a wedge with the thin end seawards, then twice the average would give us the maximum rate of deposition: this would be one foot in 120 years. But the sheets of deposited sediment are not merely thicker towards the land, thinner towards the sea, they also increase in thickness towards the rivers in which they have their source, so that a very obtuse-angled cone, or, better, the down-turned bowl of a spoon, would more nearly represent their form. This form tends to disappear under the action of waves and currents, but a limit is set to this disturbing influence by the subsidence which marks the region opposite the mouth of a large river. By this the strata are gradually let downwards, so that they come to assume the form of the bowl of a spoon turned upwards. Thus a further correction is necessary if we are to arrive at a fair estimate of the maximum rate of deposition. Considering the very rapid rate at which our ancient systems diminish in thickness when traced in all directions from the localities where they attain their maximum, it would appear that this correction must be a large one. If we reduce our already corrected estimate by one sixth, we arrive at a rate of one foot of sediment deposited in a century.

No doubt this value is often exceeded; thus in the case of the Mississippi River the bar of the south-west pass advanced between the years 1838 and 1874 a distance of over 2 miles, covering an area 2·2 miles in width with a deposit of sediment 80 feet in thickness; outside the bar, where the sea is 250 feet in depth, sediment accumulates, according to Messrs. Humphreys and Abbot, at a rate of 2 feet yearly. It is quite possible, indeed it is very likely, that some of our ancient strata have been formed with corresponding rapidity. No gravel nor coarse sand is deposited over the Mississippi delta; such material is not carried further seawards than New Orleans. Thus the vast sheets of conglomerate and sandstone which contribute so largely to some of our ancient systems, such as the Cambrian, Old Red Sandstone, Millstone Grit, and Coal Measures, must have accumulated under very different conditions, conditions for which it is not easy to find a parallel; but in any case these deposits afford evidence of very rapid accumulation.

These considerations will not tempt us, however, to modify our estimate of one foot in a century; for though in some cases this rate may have been exceeded, in others it may not have been nearly attained.

Closely connected with the rate of deposition is that of the changing level of land and sea; in some cases, as in the Wealden delta, subsidence and deposition appear to have proceeded with equal steps, so that we might regard them as transposable terms. It would therefore prove of great assistance if we could determine the average rate at which movements of the ground are proceeding; it might naturally be expected that the accurate records kept by tidal gauges in various parts of the world would afford us some information on this subject; and no doubt they would, were it not for the singular misbehaviour of the sea, which does not maintain a constant level, its fluctuations being due, according to Professor Darwin, to the irregular melting of ice in the polar regions. Of more immediate application are the results of Herr L. Holmström's observations in Scandinavia, which prove an average rise of the peninsula at the rate of 3 feet in a century to be still in progress; and Mr. G. K. Gilbert's measurements in the great Lake district of North America, which indicate a tilting of the continent at the rate of 3 inches per hundred miles per century. But while measurements like these may furnish us with some notion of the sort of speed of these changes

they are not sufficient even to suggest an average; for this we must be content to wait till sufficient tidal observations have accumulated, and the disturbing effect of the inconstancy of the sea-level is eliminated.

It may be objected that in framing our estimate we have taken into account mechanical sediments only, and ignored others of equal importance, such as limestone and coal. With regard to limestone, its thickness in regions where systems attain their maximum may be taken as negligible; nor is the formation of limestone necessarily a slow process. The successful experiments of Dr. Allan, cited by Darwin, prove that reef-building corals may grow at the astonishing rate of 6 feet in height per annum.

In respect of coal there is much to suggest that its growth was rapid. The carboniferous period well deserves its name, for never before, never since, have Carbonaceous deposits accumulated to such a remarkable thickness or over such wide areas of the earth's surface. The explanation is doubtless partly to be found in favourable climatal conditions, but also, I think, in the youthful energy of a new and overmastering type of vegetation, which then for the first time acquired the dominion of the land. If we turn to our modern peat-bogs, the only carbonaceous growths available for comparison, we find from data given by Sir A. Geikie that a fairly average rate of increase is 6 feet in a century, which might perhaps correspond to one foot of coal in the same period.

The rate of deposition has been taken as uniform through the whole period of time recorded by stratified rocks; but lest it should be supposed that this involves a tacit admission of uniformity, I hasten to explain that in this matter we have no choice; we may feel convinced that the rate has varied from time to time, but in what direction, or to what extent, it is impossible to conjecture That the sun was once much hotter is probable, but equally so that at an earlier period it was much colder; and even if in its youth all the activities of our planet were enhanced this fact might not affect the maximum thickness of deposits. An increase in the radiation of the sun, while it would stimulate all the powers of subaërial denudation, would also produce stronger winds and marine currents; stronger currents would also result from the greater magnitude and frequency of the tides, and thus while larger quantities of sediment might be delivered into the sea they would be distributed over wider areas, and the difference between the maximum and average thickness of deposits would consequently be diminished. Indications of such a wider distribution may perhaps be recognised in the Palæozoic systems. Thus we are compelled to treat our rate of deposition as uniform, notwithstanding the serious error this may involve.

The reasonableness of our estimate will perhaps best appear from a few applications. Fig. 2 is a chart, based on a map by De Lapparent, representing the distribution of land and sea over the European area during the Cambrian period. The strata of this system attain their maximum thickness of 12,000 feet in Merionethshire, Wales; they rapidly thin out northwards, and are absent in Anglesey; scarcely less rapidly towards Shropshire, where they are 3,000 feet thick; still a little less rapidly towards the Malverns, where they are only 800 feet thick; and most slowly towards St. David's Head, where they are 7,400 feet thick. The Cambrian rocks of Wales were in all probability the deposits of a river system which drained some vanished land once situated to the west. How great was the extent of this land none can say; some geologists imagine it to have obliterated the whole or greater part of the North Atlantic Ocean. For my part I am content with a somewhat large island. What area of this island, we may ask, would suffice to supply the Cambrian sediments of Wales and Shropshire? Admitting that the area of denudation was ten times as large as the area of deposition, its dimensions are indicated by the figure *a b c d* on the chart. This evidently leaves room enough on the island to furnish all the other deposits which are distributed along the western shores of the Cambrian Sea, while those on the east are amply provided for by that portion of the European continent which then stood above water.

If one foot in a century be a quantity so small as to disappoint the imagination of its accustomed exercise, let us turn to the Cambrian succession of Scan-

dinavia, where all the zones recognised in the British series are represented by a column of sediment 290 feet in thickness. If 1,600,000 years be a correct estimate of the duration of Cambrian time, then each foot of the Scandinavian strata must have occupied 5,513 years in its formation. Are these figures sufficiently inconceivable?

In the succeeding system, that of the Ordovician, the maximum thickness is 17,000 feet. Its deposits are distributed over a wider area than the Cambrian, but they also occupied longer time in their formation; hence the area from which they were derived need not necessarily have been larger than that of the preceding period.

Great changes in the geography of our area ushered in the Silurian system: its maximum thickness is found over the Lake district, and amounts to 15,000 feet;

FIG. 2.—Chart of the distribution of land and sea, and of the thickness of deposits of the Cambrian system. The dotted lines indicate distances of 100 and 200 miles from the shore.

but in the little island of Gothland, where all the subdivisions of the system, from the Landovery to the Upper Ludlow, occur in complete sequence, the thickness is only 208 feet. In Gothland, therefore, according to our computation, the rate of accumulation was one foot in 7,211 years.

With this example we must conclude, merely adding that the same story is told by other systems and other countries, and that, so far as my investigations have extended, I can find no evidence which would suggest an extension of the estimate I have proposed. It is but an estimate, and those who have made acquaintance with 'estimates' in the practical affairs of life will know how far this kind of computation may guide us to or from the truth.

This Address is already unduly long, and yet not long enough for the magnitude of the subject of which it treats. As we glance backwards over the past we

see catastrophism yield to uniformitarianism, and this to evolution, but each as it disappears leaves behind some precious residue of truth. For the future of our science our ambition is that which inspired the closing words of your last President's Address, that it may become more experimental and exact. Our present watchword is Evolution. May our next be Measurement and Experiment, Experiment and Measurement.

The following Papers were read:—

1. *Notes on the Geology and Palæontology of Patagonia.* *By* W. B. Scott, *Princeton University.*

For the past four years Princeton University has been conducting explorations in Patagonia under the direction of Mr. J. B. Hatcher. The large expenses of the undertaking have been defrayed by the generosity of friends in New York and Baltimore, and Mr. J. Pierpont Morgan has given the sum of 5,000*l.* for the publication of the important results which Mr. Hatcher has obtained.

The oldest sedimentary formation observed is a marine Cretaceous found in the Cordillera; the Ammonites of this horizon have been studied by Mr. Stanton, and he reports that they indicate Gault age and show close relationship to the Uitenhage beds of South Africa.

The oldest marine Tertiaries are given in the section near the Straits of Magellan, and my assistant, Dr. Ortmann, informs me that the fossils point to a late Eocene or Oligocene age for these beds, which he has called the Magellanian beds. These are overlaid by the great Patagonian formation, which is of great extent, of marine origin, and richly fossiliferous. The 200 species of marine invertebrate fossils obtained from this horizon have been studied by Dr. Ortmann, and lead to some very interesting conclusions. In the first place they unequivocally demonstrate the Miocene age of the beds (not Cretaceous and oldest Eocene as Ameglimo has maintained), and in the second place they display the closest resemblance to the Miocene of Australia and New Zealand, pointing to a shore connection with those countries in Miocene times. The Patagonian and supra-Patagonian stages are shown not to be distinguishable.

The Santa Cruz beds, a fresh-water and terrestrial formation, overlie and partially dovetail in with the Patagonian. They contain an incredibly abundant and varied mammalian fauna, of which a vast collection was brought home. This fauna has only a very remote connection with the Miocene mammals of the northern hemisphere, and strongly confirms Rütimeyer's contention of a southern centre of distribution. The presence of numerous carnivorous marsupials (there are no true Carnivora) is additional evidence of a connection, direct or indirect, with Australia.

Unconformably overlying the Santa Cruz is another marine formation, discovered by Mr. Hatcher and by him named the Cape Fairweather beds. The fossils indicate the Pliocene age of these beds.

Mr. Hatcher's labours have thus resulted in proving that Patagonian geology is in complete accord with the system established for the northern hemisphere, and that it is not of such exceptional character as has been supposed.

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2. *On the Order of the Formation of the Silicates in Igneous Rocks.* *By* Prof. J. Joly, *M.A., D.Sc., F.R.S.*

The viscous properties of fused silica are shown, by experiments on the stretching of 'quartz fibres,' to extend to temperatures so low as 715° C. The silica fibre develops crystalline structure at 1040° C. Rock crystal in fine powder exposed on the platinum ribbon of the meldometer to a temperature of 1100° C. for four hours shows distinct evidence of fusion. At 1200° C., falling to 915° C. in eighteen hours, its fusion and incipient recrystallisation are easily accomplished.

The principal silicates under prolonged heating (four hours) melt at tempera-

tures which in all cases are inferior to the melting points determined on brief observation. It is found that silicates of low percentage of silica show a less depression of melting point than those of high silica percentage, the result being that the melting points as newly determined fall into general harmony with the normal order of consolidation.

The suggestion is offered that the time required for the crystallised silicates to assume the appearance of fusion is a rough measure of the stability of the crystalline aggregate under conditions of high temperature; for, in fact, it is a measure of the crystalline rigidity opposing the unbalanced molecular surface-force. It is shown that if this be accepted the stability-relations of the silicates with one another may, according to the experiments, vary with temperature. Thus the manner in which the time required to effect fusion varies with the temperature in the cases of leucite and augite would indicate that in a high temperature magma the stability of leucite may be greater than augite, and leucite may crystallise in advance of augite. At lower temperatures augite is the more stable, and would be idiomorphic towards leucite. In a cooling magma every stage of mutual relations may arise. There will be one temperature for such substances at which the stabilities are equal, and at this temperature, phenomena of intergrowth, such as pegmatitic development, will be favoured.

Quartz may separate idiomorphically in a high temperature magma, being at high temperatures more stable than most of the silicates, or it may be left over as a residual constituent in a low-temperature magma, most of the ferro-magnesian silicates being more stable at low temperatures. Again at low temperatures its stability and that of the felspars approximate, and pegmatitic intergrowth as a frequent residuum is accordingly to be expected.

The normal order of consolidation follows in general that of the maximum stabilities of the silicates, that is, their stabilities at low temperatures. Abnormalities of order may be expected to arise more especially in connection with rapid cooling of a magma for long preserved under conditions of high temperature.

Appearances of magmatic instability, such as resorption, alteration of species, corrosion, &c., are ascribed to changes in the stability relations of the silicates with descending temperature.

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3. *On the Geological Age of the Earth as indicated by the Sodium-contents of the Sea.* *By* Prof. J. Joly, *D.Sc., F.R.S.*—See Reports, p. 369.

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4. *Some Experiments on Denudation in Fresh and Salt Water.* *By* Prof. J. Joly, *D.Sc., F.R.S.*

The question of the relative rates of solution in fresh and salt water of the more important rock materials is considered in this paper, which records the results of experiments on basalt, orthoclase, obsidian, and hornblende.

In these experiments equal weights of fresh material in the same state of subdivision are exposed to the solvent action of fresh and salt water under like conditions of temperature, aëration, &c.

In order to secure full aëration, in one set of four duplicate experiments on the substances mentioned, the material is treated in the form of fine powder, and the solvent containing it maintained in motion by a continuous stream of filtered and moistened air escaping in bubbles at the bottom of the containing vessel. The maintained action of atmospheric carbon dioxide and oxygen is thus secured. After three months' continuous exposure to these conditions the solvent was removed and analysed.

In a second form of experiment, confined to basalt, the fresh material is brought to the grain of a fine sand, and is placed in U-tubes through which the solvent passes alternately in opposite directions, air being freely admitted. This experiment lasted for four months, the circulation of the solvent being maintained for six hours daily.

In the final results the analyses of the salt-water solutions are compared with the analyses of unused samples of the sea water.

The results in all cases ascribe to the sea water solvent effects greatly exceeding those of fresh water, contrary to what is generally believed to be the case. Although it was found impossible to estimate the alkalies and magnesia taken up by the sea waters, the total estimated amount of material taken into solution is from $2\frac{1}{2}$ to 14 times the mass determined in the fresh-water solutions, the preponderance being specially marked in the lime. Complete analyses of the sea water would, of course, ascribe a still greater preponderance to its activity. The preponderance of activity is most marked in the cases of orthoclase and hornblende. Obsidian proved to be the most insoluble of the substances dealt with.

The consideration of the application of these experiments to the relative rates of marine and atmospheric denudation is deferred till other experiments are completed, as this question also involves the conservative action of exhausted materials precipitated or left *in situ*. But the experiments as they stand show that the conclusion often drawn from Daubrée's well-known experiment with orthoclase exposed to the solvent action of chloride of sodium solution is erroneous, sea water in presence of the atmosphere being a much more active solvent of rock materials than fresh water.

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5. *The Inner Mechanism of Sedimentation.* *By* Prof. J. Joly, *D.Sc., F.R.S.*

The precipitating effects of marine salts on suspended particles of clay, &c., are responsible for geological effects of great magnitude. This paper is occupied by an account of experimental work directed to the investigation of the inner mechanism of these actions.

It is shown that the precipitating effects of salts in solution in general vary with the valency of the electro-positive ion and (within certain limits) according to the same law as obtains in the case of the coagulative power exerted by electrolytes on colloids. At very extreme dilutions a further remarkable activity of triad salts is revealed.

These actions are ascribed to the electrical effects of the ions which by their free charges neutralise the repulsive 'electric layers' of the immersed particles, bringing about flocculation, when precipitation follows, the theory being similar to that which has been applied to colloids.

The extension of the theory to the larger particles involved in sedimentation is considered. It is shown that larger particles, by diminishing the element of chance entering into the encounters of ions with particles, will tend to conceal the valency effects. Conformably with this it is found that the finer sediments require more concentrated solutions than the coarser to produce equal effects. Similarly it is shown that at high concentrations the effects dependent on the amount of charge carried by the ion (the valency effects) should be concealed. In agreement with this it is observed that concentrations above about 0·5 gram equivalents per litre produce flocculative effects equal in degree in monad, diad, and triad salts.

The flocculative effects of the constituents of sea water are compared, and it is shown that, owing to its monad valency, the chloride of sodium, although so largely preponderating, produces effects no greater than the separate effects of the magnesium chloride and magnesium sulphate present, and rather inferior effects to the calcium sulphate.

Applications to geology follow. The compacting of marine sediments and the deposition in bulk of the finer detrital sedimentary rocks are ascribed to the ionisation in the sea of the salts dissolved by denudation from the rocks.

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6. *On Tidal Sand Ripples above Low-water Mark.* *By* VAUGHAN CORNISH, *M.Sc., F.C.S., F.R.G.S.*

In the third Report of the Committee appointed to investigate the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models (Cardiff meeting, 1891), Professor Osborne Reynolds writes:—'The large tidal sand ripples below low water in the model estuaries, with the flood and ebb taking the same course, constitute a feature which it is impossible to overlook, yet the existence of corresponding ripples had been entirely overlooked in actual estuaries until they were found to exist when they were looked for, having been first seen in the models. The reason that they were overlooked before is, no doubt, explained by the fact that the bottom is not visible below low-water mark in actual estuaries; but this is not all. In the estuaries these ripples, where found, have been confined to the bottoms and sides of the narrow channels between high sand-banks, and they do not occur on the level sands below low water towards the mouths of estuaries to anything like the same extent as in the models.'

In December 1899 the author observed that the extensive sand-banks which are exposed at every tide in the Mawddach Estuary, opposite Barmouth, North Wales, were covered, even in their highest parts, with remarkably regular series of sand ripples, averaging about 16 feet from ridge to ridge. The identity of origin of these sand ripples with the tidal sand ripples of Osborne Reynolds was soon established, and it appeared that they afforded an opportunity for more detailed study than is practicable in the case of structures beneath low-water mark. The author therefore made observations, with measurements and photographs, during the six months January–June 1900, of the sands at Barmouth (N. Wales), Grange (Lancashire), Findhorn (N.B.), Montrose (N.B.), Mundesley (Norfolk), the Goodwins, Pegwell Bay (Kent), on the Severn between Newnham and Severn Tunnel, and at Aberdovey (N. Wales).

It appears that between certain limits of speed and depth the steady action of a current can produce these ripples of regular wave-length without the agency of periodic quickenings and checkings such as operate in the formation of the ordinary ripple-mark of the strand. The author has observed in the shallow streams of sandy foreshores that a train of sand ridges of regular wave-length is produced almost instantaneously when the velocity of the stream becomes sufficient to render the water decidedly turbid with flying sand. On the other hand, a current flowing over tidal sand ripples with *clear* water can be seen to lower them. It appears probable that their formation commences at that critical velocity at which a great part of the moving sand is thrown into 'eddying suspension,' and no longer merely rolls or slides along the bottom; and that they can be produced independently of co-operation between flood and ebb, although where flood and ebb pursue the same course but in opposite directions the ridges may become more regular. The mechanism of their formation seems to be as follows: when a current, flowing over extensive sands, attains the velocity at which the sand is largely thrown into eddying suspension, then a state is soon reached in which the amount of sand dropped by the current is *on the whole equal* to the amount picked up by it, *but* any small excrescence causes a convergence of current in the lowest layers of the water ('forced towards the centre of the curve' as at the bends of rivers). Under the specified conditions as to the charge of sand held in suspension, the excrescence increases. In like manner any slight depression is deepened. 'Scour' in the troughs and 'fill' on the ridges proceeds; and this goes on until the concentration of the stream over the ridge, and its expansion above the trough, balance the effect. A considerable degree of regularity in the size and form of the ridges is soon attained, and the dimensions are limited by the depth and by the speed of the current.

Since the amplitude of the sand ridge is limited by the depth of the water, it is evident that a sand-bank in a tideway cannot dry in ridges if the final runnings of shallow water be prolonged or violent. Similarly the rising tide produces the greater effect in ridging when the first part of the flood is gentle. Thus the Dun Sands, below the junction of the Wye and Severn, being protected from rapid shallow

water currents by a rocky ridge called English Stones on the seaward side of them, are finely ridged. Fifteen consecutive ridges were found to average 37′ 8″ from ridge to ridge, and 22″ in amplitude. Above Severn Bridge, on the contrary, where the first of the flood comes almost as a bore and the ebb current, commencing long after high water, runs strongly to the last, the sands when dry are almost smooth.

In estuaries where the sand-banks dry in tidal sand ridges, their size and directions afford at a glance a good idea of the course and velocities of the streams of flood and ebb over these banks, and often show by the steep face of the ripple in what parts the flood or the ebb respectively is the stronger. The present position of the lower portion of the rivers in the valleys of Aberdovey, Barmouth, and Montrose is apparently due to the alongshore drift of beach material from the side exposed to the greatest waves. To this are also due the D shape of their tidal basins and the resulting circulation of the tide. The deep-water channel of the ebb is down the straight limb of the D, which is close under the hills which bound the valley, having been pushed as far as possible by the drift of beach material.

Tidal sand ripples above low-water mark are not confined to estuaries, being often found upon the sea-shore in places where there are strong currents. They face with the current, not with the swell, and are thus readily distinguished from wave ripple-mark. Owing to variable direction of the currents in such situations, the ripples are not generally in long straight ridges. It often happens that the only traces of the tidal sand ripples left by the receding tide on the sea-shore are pools, the characteristic section of which (like that of the print of a horse's hoof in sand) indicates that analogy with the *fuljes* of the desert which is demonstrated by the author's observations.

The complete paper, illustrated by photographs, is intended for publication in the 'Geographical Journal.'

FRIDAY, SEPTEMBER 7.

The following Papers and Reports were read:—

1. *Remarks on a Table of Strata. By* Dr. H. Woodward, *F.R.S.*

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2. *Report on Seismological Observations.*—See Reports, p. 59.

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3. *Geological Notes on the Upway Disturbance. By* Clement Reid, *F.R.S.* Appendix to Seismological Report.—See Reports, p. 108.

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4. *The Caves and Pot-holes of Ingleborough and the District. By* S. W. Cuttriss.

The portion of Yorkshire to which this paper refers is contained in Sheets 49, 50, and 60 (New Series) of the 1-inch Ordnance Survey. The great Craven Faults which traverse it in a N.W. to S E. direction have produced a difference of level of the strata of several thousands of feet; the limestones on the south side of the Faults being far below the surface.

The Silurian slates and grits form the basement beds, and are exposed in several of the valleys. On these rests the Carboniferous Limestone, which has a thickness of about 500 feet from the base to the present exposed surface on Ingleborough. The name Carboniferous Limestone is here applied only to distinguish a particular bed of rock in the district. Above this are a series of thinner limestones, shales, and sandstones (the Yoredales of Professor Phillips) capped by Millstone Grit.

Towards the west the Carboniferous Limestone has been cut off by the Dent Fault, while the Craven Faults determine its extension towards the south. The main line of fault passes through Ingleton, Clapham, and Austwick to Settle, then eastwards by Malham. North of this is another fault, near the first at Austwick, but about 1½ miles apart at Malham. Further north the most interesting caves and pot-holes are found in an area comprising the Leck Fells, Kingsdale, Chapel-le-Dale, Ribblesdale, and around Ingleborough.

The whole area may be divided into three sections:

1. The Yoredales, comprising the rocks of that name. These limestones being comparatively thin, and intercalated with beds of shale and sandstone, the caves are small and obstructed with earth, through which the water percolates. They are at an elevation of from 1,300 to 1,600 feet, and do not materially affect the drainage of the ground.

2. The Southern Carboniferous, including the Carboniferous Limestone between the two Craven Faults. Although part of the same formation as the Carboniferous Limestone north of the Fault, yet the caves in the two sections differ entirely in their characteristics. Here they are distinguished by an absence of running water, the walls are covered with a considerable thickness of calcareous deposit, and their entrances are blocked with clay and rock débris. The well-known Victoria and Attermire Caves are included in this section. A further characteristic is the entire absence of pot-holes—vertical chasms in the ground caused by falling water enlarging the rock fissures.

3. The Main Carboniferous, which includes the remainder of the Carboniferous Limestone within the area defined. Here there are no dry caves, all being active drainage channels. Pot-holes also are very abundant. In the Leck Fell and Kingsdale districts the caves are almost without exception those of engulfment, while in Chapel-le-Dale and Ribblesdale they are chiefly caves of débouchure. The first-named are usually low at the entrance. The passages then increase in height to 20 feet or more, but rarely exceed 6 feet in width, usually much narrower. Some may be traversed a quarter of a mile or more, such as Lost John's Cave, which terminates in a subterranean pot-hole over 100 feet deep. The caves of débouchure are much more numerous. The mouth is generally wide and shallow, with a flat roof. A cascade or waterfall is usually found some little distance in, beyond which the passage is a simple water-worn channel, gradually shallowing and broadening until too low to permit of further progress.

The pot-holes occur at or near the top of the limestone, at between 1,100 and 1,300 feet elevation, and always where there are surface streams, which fall into the chasms. Over thirty have been named, nearly all of which have been descended by the writer and friends, members of the Yorkshire Ramblers' Club, many of them for the first time. Half the number are over 100 feet deep. Gaping Ghyll, on Ingleborough, attains a depth of 350 feet, and was first descended by Mons. E. A. Martel in 1895 Rowten Pot, in Kingsdale, was conquered in 1897, and found to be 365 feet deep, thus being the deepest known pot-hole in the country.

No evidence of the presence of the Silurian rocks has been found, the lowest observable rock being either light or black limestone. The average summer temperature in both caves and pot-holes is 48° Fahr.

The writer has prepared a special map of the district on which are shown all the known caves and pot-holes, with the surface streams. Such a map illustrates in a forcible manner the interesting fact that the entire surface drainage of Ingleborough is swallowed up by the limestone. Not a single stream from the higher levels continues an uninterrupted course into the valley below.

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5. *The Underground Waters of North-West Yorkshire. By* Rev. W. Lower Carter, *M.A., F.G.S., Hon. Sec. Underground Waters Committee, Yorkshire Geological and Polytechnic Society.*

Part I. The Sources of the Aire.

Introduction. Description of the area investigated. The Silurian and Carboniferous rocks between Malham Tarn and Malham are traversed by two

branches of the Craven Fault with the downthrow to the south. Malham Tarn lies on Silurian, and its overflow sinks in the limestone directly the northern fault is crossed. The drainage of the area to the west of the Tarn disappears at the Smelt Mill Sink. The drainage of the area east of the Tarn is carried off by Gordale Beck, along the course of which some water sinks into the jointed limestone. To these three sinks correspond three principal outlets, the stream at Malham Cove, Aire Head Springs, and the springs at the bottom of Gordale.

The history of previous investigations is then given. From the centre of Malham Cove a dry limestone gorge runs in a northerly direction to the Tarn. Up to the beginning of this century floodwaters were known to traverse this valley and discharge over the Cove. There are several sinks along the line of this dry valley. Now all the overflow is taken by three sinks south of the Tarn.

Various efforts have been made to trace the connection between the sinks and outlets. Flushes of water from the Tarn have been shown to affect Aire Head before Malham Cove. Experiments by introducing chaff, bran, magenta, and uranin into the sinks failed to show any traces at the outlets.

The present investigation was carried out during 1899 by a Committee of Engineers, Chemists, and Geologists, appointed by the Yorkshire Geological and Polytechnic Society. Flushes of water were sent down from the Tarn to the Tarn Water Sinks. Aire Head Springs responded in two hours. With large flushes a rise in Malham Beck was also observed.

The chemical investigations were as follows:

Ammonium sulphate was put in below the Malham Tarn Sluice on June 22, and appeared at Aire Head from July 4 to 11. Distinct traces were also found at Malham Cove on the same dates.

Common salt and fluorescein, put in at the Smelt Mill Sink between June 22 and 28, appeared at Malham Cove from July 4 to 11.

Fluorescein, put in at Tranlands Beck on June 22, appeared at Scalegill Mill on June 23.

Ammonium sulphate, put into upper Gordale Beck on August 26, appeared at the springs below Gordale Scar on September 7.

Common salt, put into Cawden 'Burst' on September 18, appeared at Mire's Barn from September 23 to 27.

Fluorescein put into the bottom of Grey Gill Cave was not traced.

A geological investigation of the area showed that the limestone is traversed by two sets of prominent joints, of which the master-joints, which run in a north-west to south-east direction, are very well developed. These master-joints are found to largely determine the flow of the underground waters.

The direction of these master-joints unites the Smelt Mill Sinks and Malham Cove directly, and that may be taken as the direction of flow. A parallel line from Malham Tarn Sinks would bring the water from them to Grey Gill, a dry valley in the escarpment to the east of Malham Cove. No evidences of moving water were found there.

To the south of the Mid-Craven Fault the jointing of the limestone is found to be variable; but prominent joints were found bearing in a north-east and south-west direction. If the Tarn water followed these joints on crossing the fault it would traverse a direction almost at right angles to its previous course, and, following the limestone in its bend underneath a synclinal of Yoredale shale, would be likely to reappear at Aire Head Springs, which is the nearest point for re-emergence on the southern side of the anticlinal.

The master-joints north of the Mid-Craven Fault would similarly carry the water which sinks into the bed of Gordale Beck south-eastward into the limestone, and if, as it nears the fault, it followed a set of joints running at right angles to the previous set, it would come out at the springs at the foot of Gordale Scar, which was found to be the case by the chemical tests. Gordale itself turns in this direction from some cause.

The conclusions of the Committee are:

1. That Malham Cove Spring discharges the water from Smelt Mill Sink and

the limestone area west of the dry valley; and under certain conditions some of the Tarn water.

2. That Aire Head Springs discharge the main portion of the water disappearing down Malham Tarn Water Sinks.

3. That Gordale Beck Springs discharge the water sinking in Upper Gordale.

4. That chemicals put into Cawden 'Burst' appeared at Mire's Barn.

5. That Tranlands Beck Sinks discharge at Scalegill Mill.

6. The investigations show that within the area the main direction of underground flow is along the master-joints of the limestone.[1]

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6. *Report on the Movement of Underground Waters of Craven. The Ingleborough District.*—See Reports, p. 346.

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7. *On Ancient Plateaux in Anglesey and Carnarvonshire. By* E. Greenly, *F.G.S.*

The surface of Anglesey, considered as a whole, is seen to be composed of a series of broad ridges ranging N.E. and S.W., and so remarkably even in height as to leave little doubt that they are really portions of an undulating plateau about 200–300 ft. above the sea. Holyhead Mountain and about four other hills rise abruptly above the general level. This plateau is traversed, not bounded, by the Menai Straits, beyond which it ranges to the foot-hills of the mountain region, where a totally different type of scenery begins. The profile of this mountain region appears, when viewed from the N.W., as that of a very gentle flattened dome, rising gradually from Penmaenbach, on the N.E., till it attains a height of more than 3,500 ft. in the Carnedds and Snowdon, and declines again as gradually to Yr Eifl and Carn Boduan, in the far S.W. This, therefore, and the Anglesey plateau, would appear to be ancient platforms or base-levels; and they also appear to be distinct.

That of Anglesey must be at least of post-Carboniferous age, for Carboniferous and older rocks are levelled off indiscriminately at its surface, and if the Red rocks of the island are Permian or Triassic it must be of Mesozoic, possibly of Cretaceous, age. The age of the platform bounding the mountain region is more difficult to determine. It is tentatively suggested that this feature may pass below the Carboniferous rocks, and so be really a deeply denuded sub-Carboniferous base-level rising as the core of a broad anticlinal.

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8. *On the Form of some Rock-bosses in Anglesey. By* E. Greenly, *F.G.S.*

The general trend of the major axis of the bosses that are so marked a feature of the land surface in Anglesey coincides as a rule with the strike of the dominant structures, which is for the most part N.E.-S.W. But slight discordances are not uncommon; and in some cases, particularly among the hornblende gneisses about Craig-y-Allor, the bosses trend in the usual N.E.–S.W. direction, in spite of the fact that the banding of the gneiss strikes almost N.W.–S.E., *i.e.*, very nearly at right angles to this.

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9. *The Concretionary Types in the Cellular Magnesian Limestone of Durham. By* G. Abbott, *M.R.C.S.*

Associated with the Cannon-ball bed near Sunderland is a cellular limestone which is much more extensive, and exhibits still more remarkable physical

[1] The complete report, fully illustrated, will be published in the Proceedings of the Yorkshire Geological and Polytechnic Society, Vol. XIV., Part I.

features Although described by Professor Sedgwick more than sixty years ago with other magnesian beds in the north of England, it is still comparatively unknown. He divided the concretions in these strata into ten classes, but I have been unable to find any classified collection except the one in the Newcastle Museum; even this is only partially done.

My own studies at Fulwell and Hendon lead me to suggest a new classification, with *five primary forms*, viz. (1) rods, (2) bands, (3) rings, (4) balls and modified spheres, (5) eggs. *Combinations* of these forms constitute the major part of these massive beds, and frequently a bed of less than a foot thick shows examples of several different combinations. These I place in ten classes, though they may have to be added to. The chief types are (1) tubes, (2) 'cauliflowers,' (3) basaltiform, (4) irregular, (5 and 6) troughs and bands (two kinds), (7) 'fanlike,' (8 and 9) 'honeycomb' or coralloid (two kinds), (10) pseudo-organic.

Photographs were exhibited on the screen showing both the primary forms and the combinations as seen (wherever possible) in the undisturbed rock sections.

My own conclusions are as follows:

1. That the rod structure is *secondary* to the formation of the conspicuous bands which run across the beds at various angles. (These bands need to be distinguished from the bands mentioned among the 'primary forms.') The conspicuous bands act as planes of origin for the 'rods,' and do not cross through the long axes of the rods themselves. They appear never to cross the bedding planes, though occasionally they follow them and also the outline of the joints. The question therefore arises, whether this does not give us a clue to the age and sequence of the changes which have occurred in these beds, and whether the previous existence of joints does not mean that the beds were already above the sea-level when the changes commenced.

2. The rods invariably start from the last-mentioned bands, and may be seen at every possible angle. As they have grown upwards and obliquely as well as downwards, the term 'stalactitic' is a very misleading one to use. As Mr. Garwood stated long ago, these beds 'present many points which appear irreconcilable with the theory of their stalactitic origin.'

3. The first step in the series of changes which have taken place was probably an orderly but unsymmetrical arrangement of amorphous molecules of calcium carbonate which separated themselves from those of the carbonate of magnesia.

4. The internal architecture is due to such arrangement of amorphous particles of lime which has since been coated with an outer crystalline layer. In some cases, however, the central part has undergone a complete subsequent change into a crystalline condition.

5 Pearl-spar (crystals of the combined carbonates) is not always met with. I failed to find any.

6. In the Fulwell beds there are very few fossils, and where met with, as at Marsden, concretionary action is not always traceable near them.

7. The specimens at Fulwell which arouse the most interest are coralloid masses ('honeycomb' of the quarrymen). They are confined, so far as I could discover, to a stratum, about $1\frac{1}{2}$ foot thick, above the marl bed, and lie in close juxtaposition to each other, which accounts for their peculiar external shape.

8. Very little evidence of *erosion* of lime is to be seen anywhere; unless we may attribute the cavities in the balls and elsewhere to this cause.

In conclusion I would point out the close resemblance which exists between the 'lines' and 'planes' in these concretionary beds, and the 'lines' which shoot across congealing water. In some respects the architecture of the magnesian beds compares with the ice decorations seen on our window-panes in frosty weather.

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10. *The Pebbles of the Hollybush Conglomerate, and their bearing on Lower and Cambrian Palæogeography. By* THEODORE GROOM, *M.A., D.Sc.*

The Malvern Hills are commonly supposed to have formed part of an old coast during the deposition of the Lower Palæozoic beds. A preliminary examination

of the materials of the Hollybush Conglomerate by the author does not support this view.

The most abundant pebbles consist of *quartz*; these vary from a coarse mosaic of crystals to a fine *quartz-schist*. Most of the varieties are probably of metamorphic origin; some appear to be merely vein-quartz, and some represent the quartzose portions of granites and other rocks. Red *granites* and *granophyres*, often crushed, are tolerably abundant; these often contain microcline. *Mica-schist* and *chlorite-schist* occur rarely. Very abundant are different varieties of felsite. These appear to be mostly micro- or crypto-crystalline, and often micro-graphic, *rhyolites*, compact or porphyritic; sometimes banded, and occasionally spherulitic. Some of the varieties may represent crushed intrusive *felsites*. Far rarer than the rhyolites are microlithic *andesites*, or *andesitic basalts*. Other pebbles, and the grains of the groundmass, consist of materials derivable from the rocks mentioned above.

The resemblance of these materials to the rocks of the Malvern Range is sufficiently close to prove the Pre-Cambrian age of the latter. But striking differences in microscopic structure and in the proportionate numbers of corresponding rocks in the two series, and the absence of any relation between the local nature of the conglomerate and that of the Archæan mass nearest to it, can hardly be explained except on the assumption that the Range itself did not furnish the materials.

The stratigraphical relations of the conglomerate and Archæan mass, moreover, appear to indicate that the Malvern Hills—the southern portion at least—in Cambrian times formed part of an area of deposition, and not of denudation.

The author maintains, then, that the Malvern Hills did not form a coast-line in Cambrian times, a conclusion which is in agreement with his former contention that they arose at a much later date.

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11. *On the Igneous Rocks associated with the Cambrian Beds of Malvern.* *By* THEODORE GROOM, *M.A.*, *D.Sc.*

The igneous rocks of the Cambrian beds of the Southern Malverns have commonly been regarded as of volcanic origin. The author, after a careful examination of the rocks under the microscope, and of the ground, concludes that the scoriæ and tuffs previously described are non-existent, and that the whole of the igneous rocks are probably intrusive. They consist of silts and small laccolites of basic and ultra-basic *olivine diabase* and *olivine basalt*, in which olivine is often extremely abundant, and of bosses and dykes of peculiar amphibole bearing *andesites* and *andesitic basalts*.

Intrusion probably took place in Ordovician times.

SATURDAY, SEPTEMBER 8.

The following Papers and Reports were read:—

1. *On a Possible Coalfield in the London Basin.* *By* Professor W. J. SOLLAS, *D.Sc.*, *LL.D.*, *F.R.S.*

A very expensive and laborious investigation was undertaken some years ago to determine the dip of the Palæozoic rocks reached by deep borings at Ware and Cheshunt. The results were communicated to the Association by Mr. J. Francis on the occasion of its meeting in Ipswich in 1895. At Ware the Silurian strata, which had been reached at a depth of 797 feet, were found to dip nearly due south at an angle of 41°; at Turnford, near Cheshunt, Devonian rocks were encountered at 980 feet, and dipped a little to the west of south at an angle of 25°.

When beds occur in somewhat gently undulating folds, such as those which appear to characterise the Palæozoic rocks of the east of England, the sweep of

the synclinals can be traced with sufficient approximation by drawing lines at right angles to the dips and describing circles from the point of intersection of these lines as a centre. The thickness of the beds between any two points is given by the length of the radius intercepted by the two corresponding circles. To test this method it has been applied to cases in which the course of the synclinals was known: one of these was afforded by the section across the northern side of the South Wales coal basin, along the course of the river Sawdde, a distance of four miles; the other by the section exposed in the cuttings along the Rhymney railway through the Old Red Sandstone, north of Cardiff, nearly two miles in length; in both cases the results very closely approached the facts.

Two points at which the dips are known, such as those of Ware and Cheshunt, are sufficient to determine one side of a synclinal. From the construction obtained a basin is indicated having its axis running east and west and situated below Enfield Lock on the river Lea. Its northern half is thirteen miles in breadth, the thickness of the contained strata 29,500 feet: of this 19,000 feet are Silurian and Devonian; the remaining 7,500 feet are Devonian and Carboniferous. How much of this upper portion is Devonian is unknown, no great thickness probably, when the great thickness, 19,000 feet, of the underlying Devonian and Silurian is considered. How much of the Carboniferous consists of productive Coal-measures is also uncertain, but that there is ample room for an important coalfield is shown by comparison with the Forest of Dean: that is only eight miles in width, and the total thickness of the Carboniferous beds, upper and lower, contained by it is only 3,500 feet, while the Enfield trough is approximately fourteen miles in width and 7,500 feet in depth. An attempt to apply another method of determining the course of folds, employed by Professor Lapworth, shows that the thickness of the Enfield measures may be even greater than here given—perhaps 10,000 feet.

It is scarcely necessary to point out that faults and other troubles may exist by which these estimates may be modified, but the dip of the Devonian beds to the south, as determined by the deep boring made at Meux's Brewery, London, affords a strong confirmation of their general truth.

The strike of the beds would suggest a locality somewhat west of Enfield Lock—possibly near the town of Enfield or New Barnet—as the most promising spot for a trial boring.

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2. *On the Formation of Reef Knolls.* *By* R. H. Tiddeman, *M.A., F.G.S.*

[Communicated with the permission of the Director-General of the Geological Survey.]

At the meeting of the British Association at Newcastle in 1889 I brought out my interpretation of the probable origin of the limestone knolls of Yorkshire.[1]

It was shown that the Lower Carboniferous Rocks in the North of England had two distinct types—that the Yoredale or Northern type extended from the Craven Faults to the Tyne, and that the Southern or Bowland type occupied the country from the Craven Faults to near the Western Seaside plain and extended south as far as Derbyshire. Without now recalling the two tables of the succession there given, I mentioned specially the curious construction of certain mounds of limestone, which I called reef-knolls, and gave my reasons for supposing that they had been gradually built up on a slowly sinking sea bottom by the gradual accretion of animal remains, somewhat in a similar manner to coral reefs. I also showed that from the enormously disproportionate thickness of rocks in the area of the downthrow side and from other considerations there was every reason to suppose that the Craven Faults were actually taking place during the formation of those rocks.

My friend Mr. J. E. Marr, F.R.S., has in a most courteous way, whilst taking

[1] *Report Brit. Assoc.*, 1889.

my geological mapping as for the most part correct, found reasons for dissenting with all the groundwork on which it was founded.[1]

In combating Mr. Marr's views I offer no opinion on knolls of other localities or other ages which he brings forward in support of his views. I speak only of the Carboniferous knolls of which I have written, and with which I am well acquainted. Speaking generally, I think the differences between us may be thus summarised:

1. Mr. Marr disagrees with my reading of the succession and thickness of the rocks on the south side of the Craven Faults, and, whilst I consider that we have two distinct successions of different thickness caused by a difference in the rate of submergence in the two districts, and by shallower and deeper seas, he regards the rocks on both sides as having been one series of like thickness in orderly sequence to the north, but, so to speak, shuffled by earth movements on the south of those faults and repeated several times by over-thrusts.

In illustration let us take a pack of cards, say arranged in suits as representing the regular country on the north side, and several packs similarly arranged to represent the greater thickness on the south side. Shuffle these last to represent the supposed disturbance and over-thrusting. Shall we always find after shuffling the same general succession? Yet over a tract reaching from Draughton to Chipping and from Settle to Derbyshire, we do get such a general succession, and that does not at all resemble the succession on the north side of the faults. The over-thrusting to do this effectually must cover the whole of this wide area comprised in three or four counties and not confine its operations to a narrow disturbed belt near the Craven Faults. Is Mr. Marr prepared to make his orogenic movements extend over so large an area, and thereby arrange the whole country, which they break up, into so orderly a disposition?

2. Mr. Marr regards the great difference between the black and white limestone, the form and constitution of the reef-knolls, the abundance in them of perfect fossil forms in a well-preserved state, the conglomerates and breccias which accompany them, as all being the result of what he calls orogenic movements; in other words, of the folding, repetition, and over-thrusting of the rocks, with here and there *relief of pressure*. More especially is the last called in as being the reason for the abundant and well-preserved fossils and the change of the limestones.

It is extremely difficult for me to accept these views. If we could believe that a black, well and thinly bedded limestone can by any physical change be converted into a white crystalline mass with little visible bedding, but with abundant fossils in a perfect state, we have still to learn what has become of the shales which are almost always present with the black limestone. If squeezed out, as might be suggested, they would at least leave partings behind, and the rock would be more bedded than it is.

Mr. Marr contemplates the likelihood of several different limestones being shifted together to make one reef-knoll, but if so, are we not as likely to get the thin sandstones of the Pendleside Grit sandwiched into them as well? Yet sandstones and shale-beds are unknown in the reef-knolls.

Mr. Marr makes a number of statements about what he calls the Vs of the Middle Craven Fault. His opinion is that this is a great thrust plane dipping gently north, and that the Coal-measures are forced beneath the limestone, and so on along its course. A bed of coal in the limestone at Ingleton is regarded by him as having been forced up from underlying Coal-measures by pressure, and not as originally interbedded. Unfortunately for these views, there are no proper Vs or dipping planes of faulting indicated in the map. The sinuous track of the Craven Fault is not so drawn to accommodate any theory, but is merely put where the exposures of rock show it to run. Its wanderings are either dictated by or stand in relation to the two principal lines of jointing in the limestone, which range W.N.W. and N.N.W. Sometimes one direction, sometimes the other, has the mastery. At Clapham the line is absolutely straight, and does not curve up

[1] *Quart. Journ. Geol. Soc.*, vol. lv. pp. 327–361.

stream as suggested by Mr. Marr. The coal seam mentioned is well known to me. On searching it I found several Producti fairly perfect embedded in it and filled with it, and the conclusion I came to was that it was either a coal-seam which had grown on a reef and been submerged, or a deposit of seaweed. These Producti seem to disagree with the injection theory. Such coal-seams are found occasionally in the limestone. One near Kirkby Lonsdale has been worked for coal.

Mr. Marr has mentioned two places where knolls of grit occur. I do not admit that a knoll of grit can have anything in common with the reef knolls of Craven unless it be the external form; but if such structures were made by earth thrusts and abounded, it would no doubt be a strong point in favour of his views. One of these grit knolls is said to be in the canal at the back of Shipton Castle. I think this must be an error. I know of no sandstone in that locality, though I know it well. I have consulted others who are, as geologists conversant with Shipton, competent to form an opinion, and they agree with me that nothing but limestone and shales occurs in that canal at that point. The beds there are certainly contorted, but not sandstone, and contortions do not necessarily imply reef-knolls.

I feel unable to regard Mr. Marr's 'model knoll' as in any respect resembling what I have called reef-knolls. That is, according to his views, a broken plication of a thin hard bed of limestone in a mass of softer shale, the shale surrounding its broken fragments. The knolls to which I allude are almost solid limestone from top to base. They have no alternations of hard and soft beds, and, so far as I have seen, no repetition of beds by folding. The evidences of movement on their flanks, if any, are not more than one would expect from the vertical pressure of a more or less plastic shale upon what is at least a less plastic limestone.

I admit fully that there are abundant evidences in the district of faulting, of great pressure, and quite likely of over-thrusts; but to say that these have given to these rocks a change of character, or are responsible for the order of their succession, appears to me to be invoking an unnecessarily powerful but yet inadequate force. Such thrust-planes as are implied would meet the geologist in the field at every turn, and force themselves into recognition. They would admit of easy mapping, and no statement of their existence can be complete without some such systematic recognition.

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3. *On the Construction and Uses of Strike Maps.* *By* J. Lomas, *A.R.C.S., F.G.S.*

In studying the deformations which a series of rocks have undergone, we are apt to regard the vertical movements as all-important, and neglect the horizontal movements to which they have been subjected. This is largely owing to the difficulties experienced in picturing such horizontal movements and representing them on a plan.

Lines dependent on surface inequalities confuse the worker when he seeks to use the ordinary geological maps for this purpose.

It is easy to get rid of these lines by projecting the strikes of the beds on to a horizontal plane. We then have the appearance that would be produced if the country were planed down to a horizontal surface. The outcrops would coincide with the strikes, and any deviation from straight lines would indicate horizontal movements.

Vertical movements would also be shown on such a plan by the closing up of outcrops of beds of equal thickness.

All the necessary data necessary to represent these features on a strike map are given in the ordinary Geological Survey Sheets.

To construct such a map, first trace the dips given on the geological map and draw short lines at the points of the arrows, at right angles to the direction of dip.

We thus have represented the strikes of the beds at a number of points. Now it is necessary to connect these up by lines to show the strike at intermediate places.

It would not be safe to connect one line with another, as the strikes may refer to different beds.

In order to overcome this difficulty, draw a series of lines parallel to the strike line on both sides of it. On doing this for all the positions it will be found that the lines either connect themselves in linear series, or we have represented a series of tangents to curves which become evident when the lines are prolonged in the direction of the strike. Care should be taken not to connect in the same line strikes with dips in contrary directions, and it is well to represent the dip side of the strike lines by a short mark ‾‾‾'‾‾‾.

When the amount of dip is known, as well as the direction, we can represent the steepness of the folds by suitable shading, either by hachures or closeness of strike lines.

As an illustration I exhibit strike maps of the district about Clitheroe, including the well-known knolls at Worsa and Gerna. The anticlinal ridge just north of Chatburn is clearly shown, and the strata dipping with wavy folds towards the Ribble on the north and Clitheroe on the south.

The Salt Hill quarries are excavated in this southern slope at a place where the fold becomes acute.

The knolls at Worsa and Gerna appear like whirls or eddies such as may be seen in a stream when the flow is obstructed by boulders in the stream bed.

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4. *On Rapid Changes in the Thickness and Character of the Coal Measures of North Staffordshire. By* W. GIBSON, *F.G.S.*

[Communicated by permission of the Director-General of H.M. Geological Survey.]

Variability in thickness and character of the strata is universal throughout the Carboniferous period, but is nowhere more marked in the Midlands than in the coalfield of the North Staffordshire Potteries

This important coalfield consists of two portions. On the east the productive measures lie in a well-marked syncline, while on the west the strata rise in a sharp anticline extending from Silverdale to Talke. The two productive areas are separated by a strip of ground two and a half miles broad, composed of barren upper measures.

A notable difference in the thickness of the strata and nature of the coal seams characterises these structurally distinct areas. In the centre of the syncline, near Shelton, the vertical distance between the highest ironstone, or summit of the productive measures, to the Bullhurst coal, or lowest workable seam, is about 1,300 yards. On the anticline at Apedale only 800 yards of strata separate the same horizons. This makes a remarkable decrease in thickness of 500 yards of strata in a distance of under three miles. The reduction in thickness westward of the productive measures is continued, though in a less degree, in the upper barren series, but owing to the absence of shaft sections the amount cannot be definitely stated It is known, however, that the red marls forming the lower portion of the upper barren series are more than 1,000 feet thick near Etruria station on the Shelton property, and about 850 feet thick near Silverdale, on the south-eastern limb of the anticline. With the decrease in thickness a change has taken place in the lower coals of the productive series. The seams which are house or steam coals on the east change into gas and coking coals on the west.

This great variability seems to show that separate areas of deposit were being marked out by local movements of elevation and depression, and thus fulfilling in North Staffordshire the conditions characteristic of the Carboniferous of the Midlands generally, as pointed out by Prof. Lapworth.[1]

In North Staffordshire it happens that the areas of maximum and minimum deposit correspond with a syncline and anticline. If this is true generally, and not merely a local coincidence, we may expect the coals in the unexplored coalfield which lies at the surface to the west of the anticline, and which represents the

[1] *A Sketch of the Geology of the Birmingham District* (*Geol. Assoc.*), 1898, p. 364.

eastern margin of the great synclinal of coal measures beneath the Cheshire plain, to be of a different quality from those in the anticline, while the thickness of the measures will be increased.

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5. *Report on the Registration of Type Specimens.*—See Reports, p. 342.

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6. *Suggestions in regard to the Registration of Type-fossils. By* Rev. J. F. Blake.

Whereas:

1. There is now in existence, and has been for some time, a Committee of the British Association 'to consider the best methods for the registration of all type specimens of fossils in the British Isles.'
2. There is as yet in course of production no general register of such specimens.
3. The original types are in many, perhaps the majority of, cases either lost, inaccessible, or inadequately preserved or described.
4. Many names in common use have a foreign origin which have not been adopted after actual comparison with the original foreign types.
5. Palæontological nomenclature consequently still remains burdened with names of uncertain value.

It is therefore advisable that—

1. The above-named Committee recognise and register a new class of 'types,' which may be either original or adopted, but which satisfy certain conditions laid down to insure their having a definite value.
2. A register be published annually of such types, so that an author in using a name may have the option of quoting this register, instead of the original author's name.
3. This register should give references (1) to the author or authors, and their publications thereupon, who have first satisfied the required conditions; (2) to the museum where the type is deposited.
4. The limitation of types, registered by the *British Association*, should have reference to the type specimens, whatever their origin, which are deposited in museums within the United Kingdom (possibly to be enlarged at a future date to the British Empire).
5. The Committee should, from time to time, determine the conditions required for registration, but should be in no way responsible for the validity of the 'species' to which the type may be said to belong, or for the name under which it is registered, which registration should apply to the 'specific' name only and not be affected by its reference later to another genus; the only care of the Committee, beyond seeing that the required conditions are satisfied, being to secure that identical diagnoses are not registered under different names, and that the same name is not used at different times for different diagnoses.

The *suggested* conditions for registration are as follows:

1. A single specimen must be selected as the type, but two or more co-types may be admitted, which are identical in all other respects than the preservation of different necessary characters.
2. The exact horizon and locality of the specimen thus selected must be known.
3. All the commonly called 'specific' characters required, in the class to which it belongs, must be known by the type or by the co-types together, and also described, and also the generic ones when the genus is not obvious. [N.B.—The determination whether this condition is carried out in any particular case will rest with the member of the Committee charged with the class.]

4. All characters, capable of numerical statement, including size, proportion of parts or lines, angle, &c., must be so given. [N.B.—Adequate figures may suffice for this.]

5. The type specimen must be permanently placed in a public museum in the United Kingdom.

N.B.—It is not necessary that the type specimen in the above sense should be the first anywhere described under the registered name, but only the first that satisfies the above conditions.

It is suggested that registered types should be quoted as B 1, B 13—e.g. *Terebratula biplicata*, B 1, or *Phacops caudatus*, B 13—B standing for British, and the number for that of the year of the century. Specimens differing notably from the type, but included in the same species, might be quoted as (B 1).

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7. *The Outcrop of the Corallian Limestones of Elsworth and St. Ives.* *By* C. B. Wedd, *B.A., F.G.S.*

[Communicated by permission of the Director-General of H.M. Geological Survey.]

The ferruginous and oolitic limestones known as the Elsworth and St. Ives Rocks are now generally believed to be one and the same, an opinion supported by my own work in that district recently. The limestone in question has long been known to occur at St. Ives in brick-pits, being well exposed to the west of the town. It was known also to occur throughout the village of Elsworth. Mr. Cameron noticed a fossiliferous rock outcropping near Hilton, between Elsworth and St. Ives. No other surface exposures were known, but a similar rock was found in the railway cutting at Bluntisham, north-east of St. Ives, at Swavesey, east of the same place, and Bourn, south of Elsworth, and a few other localities, and like rock was found in Wells.

The outcrop can be traced almost continuously from a mile west of the brick-yard at St. Ives, striking eastwards along the northern flank of the Ouse valley, and passing north of St. Ives to Needingworth; here it bends abruptly southwards to Holywell and forms a gentle rise. The southern part of the village of Holywell stands on a gravel-capped escarpment of the rock; a collection of fossils in the Woodwardian Museum, Cambridge, agreeing closely with those of the Elsworth and St. Ives Rocks, was believed to have come from Holywell. East of Holywell the outcrop must cross the Ouse valley; I found traces of the rock in a drain some distance west of Swavesey. From here, south-westwards, it is not seen again till it appears at the surface between Hilton and Conington, where a rock was noted by Mr. Cameron. Southwards from here the outcrop crosses a valley to the rising ground west of Elsworth, through which village a narrow tongue of the rock runs still further south. The main outcrop, however, flanks the northern slope of the drift-capped high ground to the west, and can be traced along the slope through Papworth Everard, westwards to Yelling, following the contour of the ground. At both of these localities there are good and highly fossiliferous exposures in streams. Thence the outcrop disappears southwards under drift, but the rock may be seen again to the south, less than two miles south of Croxton, in a ditch in the valley of the Abbotsley Brook.

To the north, east, and south-east of the line of outcrop of this limestone, the ground is occupied by Ampthill clay, to the west by Oxford clay. It will thus be seen that the Elsworth and St. Ives Rocks, besides agreeing closely in their fauna, outcrop along the same line of strike, with Ampthill clay above and Oxford clay below. The dip is always small, and the rock at Bluntisham, if it reaches the surface at all, does so probably as an inlier, though it may be directly connected at the surface with the outcrop east of St. Ives.

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8. *Report on the Exploration of Caves at Uphill, near Weston-super-Mare.*

See Reports, p. 342.

9. *Report on the Exploration of Irish Caves.*
See Reports, p. 340.

MONDAY, SEPTEMBER 10.

A joint Discussion with Section K on the Conditions under which the Plants of the Coal Period grew was opened by the reading of the following Papers:—

Flora of the Coal-measures. By R. KIDSTON.

Leaving out of consideration for the meantime a few genera of which we possess little or no definite knowledge, the flora of the Coal-measures consists of *Ferns, Calamites, Lycopods, Sphenophylleæ, Cordaites,* and *Coniferæ.*

In genera and species the ferns are probably more numerous than the whole of the other groups, and contain representatives of the Eusporangiate and Leptosporangiate members of the class. The Eusporangiate, or those ferns whose sporangia are unprovided with an annulus, were more numerous in the Carboniferous period than at present, though in the Coal-measures they do not appear to have been more numerous than the genera with annulate sporangia. Tree ferns, though not very common, are more frequent in the Upper than in the Lower Coal-measures, in the lowest beds of which they seem to be very rare.

The Calamites are largely represented throughout the whole of the Coal-measures, *Asterophyllites* (*Calamocladus*) and *Annularia* probably being their foliage.

Lycopods are also very numerous, and are represented by many important genera—*Lycopodites, Lepidodendron, Lepidophloios, Bothrodendron,* and *Sigillaria,* with their rhizomes *Stigmaria* and *Stigmariopsis.* These genera contributed largely to the formation of Coal.

The genus *Sphenophyllum* was also frequent during Coal-measure times, and forms a type of vegetation essentially distinct from any existing group.

The Gymnosperms are represented by *Cordaites, Coniferæ,* and *Cycads.*

The *Cordaites* had tree-like trunks and long yucca-like leaves. They are plentiful in the Coal-measures, and, like the arborescent lycopods, must have been a prominent feature in a Carboniferous forest-scene.

The *Coniferæ,* so far as I have seen, are only represented by a single specimen of *Walchia* from the Upper Coal-measures; and though Cycads have been discovered in the Upper Coal-measures on the Continent, I am not aware of any British species which can be referred with certainty to this group.

The Origin of Coal. By A. STRAHAN, *M.A.*

The deposition of the Coal-measures was due to the subsidence of large portions of the earth's crust to a depth often amounting to several thousand feet. The subsidence, being unequal, led to the formation of coal-basins, parts of the margins of which are still recognisable. That the intervening areas rose no less rapidly than the basins sank is proved by the vast denudation suffered by the earlier Palæozoic rocks during the Carboniferous period.

The subsidence was counterbalanced during Coal-measure times by sedimentation, for the occurrence of marine beds among deposits of a generally estuarine aspect proves that the surface was maintained at or near sea-level. The Carboniferous sediments consist, in the majority of coal-fields, of marine limestones in the lower part, of marine grits and conglomerates in the middle part, and of estuaro-marine sandstones and shales in the upper part. The sequence is due, firstly, to the admission of the sea to the subsiding areas; and lastly, to the restoration of level brought about by sedimentation and denudation. But there is evidence also of the sedimentation having been more or less spasmodic. Thus the Limestone Series generally consists of repetitions of small groups of strata,

each group being composed of sandstone, followed by shale, shale followed by limestone. Similarly the Coal-measures present repetitions of sandstone followed by shale, shale by coal. Limestone in the one case and coal in the other are therefore comparable in the respect that each represents an episode when sedimentation had come to a pause. Early views as to the origin of coal, namely, that it was formed of vegetable matter drifted beyond the region to which the finest mineral sediment could reach, were in accordance with these facts.

More minute examination of the strata, however, revealed proofs of land-surfaces in the Coal-measures, and it was generally accepted that the coal-seams represent forests in the place of their growth. The evidence may be summarised as follows:—

1. Rain-pittings, sun-cracks, and footprints prove that the surfaces of some of the beds were exposed to the air.

2. Erect tree-trunks of large size, in some cases attached to large spreading roots, are not uncommon. Land-shells, millipedes, and the skeletons of air-breathing reptiles have occasionally been found within the hollow trunks.

3. The underclays of coal-seams are traversed in all directions by branching rootlets, unlike the drifted fragments in the bedding planes of the other strata. They were described as an invariable accompaniment of coals, and as being the soils in which the coal-forest was rooted.

4. Coal-seams, with thin minute partings, persist over vast areas, and it was thought impossible that so wide and regular a distribution of the vegetable matter could have been accomplished by drifting.

5. The chemical composition of the coals was believed to prove that the vegetable matter underwent partial decomposition in the open air before being submerged or buried.

This evidence, however, though it proves the existence of land surfaces, is not conclusive of the coal-seams being forests in place of growth. The rain-pittings, sun-cracks, and footprints occur, not in the coals, but in the intervening strata. Of the erect tree-trunks a large proportion occur in sandstones devoid of coal, a few only having been found to stand upon an underclay, or to be associated with seams of coal. Vast areas of coal have been worked without any such trunks having been encountered. The majority of the trunks, moreover, are destitute of spreading roots, and are believed to have been floated to their present positions. The land-shells, insect and reptilian remains, are of extremely rare occurrence.

The underclays do not resemble soils, inasmuch as they are perfectly homogeneous, and lie with absolute parallelism to the other members of a stratified series. They are not always present beneath coal-seams, but, on the other hand, often occur in them or above them. Frequently they have no coal associated with them. The rootlets in them have no connection with the coal, which is a well-stratified deposit with a sharply defined base.

The persistence of the partings and characters of the coal over wide areas is in favour of their being subaqueous deposits, for on so large an expanse of land there must have been river-systems and variations in the vegetation. The stream-beds, known to miners as 'wash-outs,' are not proportioned in size to the supposed land-surfaces.

Sub-aërial decomposition of part of a mass of vegetable matter would take place whether it were floating or resting on dry land. Spores, which enter largely into the composition of many coals, would travel long distances either by wind or water.

Some coal-seams show clear proof of a drifted origin, as, for example, those which are made up of a mass of small water-worn chips of wood or bark. Other seams pass horizontally into bands of ironstone, and one case has been observed of a coal changing gradually into a dolomitic tufa, doubtless formed in a stagnant lagoon. Putting aside exceptional cases, the sequence of events which preceded the deposition of a normal coal-seam seems to have been—firstly, the outspreading of sand or gravel with drifted plant-remains, followed by shale as the currents lost velocity. The water was extremely shallow, and even retreated at times, so as to leave the surface open to the air. The last sediments were extremely fine,

homogeneous, and almost wholly siliceous, and in them a mass of presumably aquatic vegetation rooted itself. This further impediment to movement in the water cut off all sediment, and the material brought into the area then consisted only of wind-borne vegetable dust or floating vegetable matter carrying an occasional boulder. Lastly, the formation of the coal-seam was brought to a close by a sudden invasion of the area by moving water. The mass of vegetable matter, often after suffering some little erosion, was buried by sandstone or shale rich in large drifted remains of plants or trees, and the whole process was recommenced.

Botanical Evidence bearing on the Climatic and other Physical Conditions under which Coal was formed. By A. C. SEWARD, *F.R.S.*

Botanical investigations into the nature and composition of the vegetation which has left abundant traces in the sediments of the Coal-measures may be expected to throw some light on the natural conditions which prevailed during that period in the earth's history that was *par excellence* the age of coal production. The minute examination of petrified tissues has rendered possible a restoration of the internal framework of several extinct types of plant-life, and has carried us a step further towards the solution of evolutionary problems. It is possible, even with our present knowledge, to make a limited use of anatomical structure as an index of life-conditions, and to restore in some degree from structural records the physiological and physical conditions of plant-life characteristic of the close of the Carboniferous epoch.

I. *Evidence furnished by the Coal-period Floras as to Climatic and other Physical Conditions.*

The uniformity in the character of the vegetation exaggerated; the *Glossopteris* flora of Australia, South Africa, and South America. The existence of botanical provinces in Upper Palæozoic times.

A comparison of the Coal-period vegetation with that of the present day as regards (i.) the relative abundance of certain classes of plants, (ii.) the geographical distribution of certain families of plants during the Carboniferous epoch and at the present day. The importance of bearing in mind the progress of plant-evolution as a factor affecting the consideration of such comparisons. The possible existence of a Palæozoic Mountain flora of which no records have been preserved.

II. *The Form, Habit, and Manner of Occurrence of Individual Plants as Indices of Conditions of Growth.*

Comparison of calamites and horse-tails. Fossil forests of calamites. *Psaronius* stems *in situ* and bearing roots at different levels, suggesting growth in a region of rapid sedimentation. Vertical stems either *in loco natali* or drifted. Climbing plants possibly represented by *Sphenophyllum*, some species of ferns and Medulloseæ. Function of the so-called *Aphlebia* leaves of ferns.

III. *Anatomical Evidence.*

The value of evidence afforded by anatomical features. Risks of comparison between structural character of extinct and recent plants. Structure considered from the point of view of evolution, as the result of adaptation to external conditions, and to mechanical and physiological requirements.

(α) *Spores and leaves.*—Abundance of spores provided with filamentous or hooked appendages; adaptation of spores to floating or to wind-dispersal. The leaf structure of calamites, ferns, &c.; presence of stomata, palisade tissue, and water-glands; the 'parichnos' or aërating tissue in the leaves of Lepidodendreæ and Sigillarieæ.

(β) *Stems and roots.*—Absence of annual rings of growth. The large size of water-conducting elements connected with rapid transport (e.g. *Sphenophyllum*) or with storage of water (e.g. *Megaloxylon*). The chambered pith of *Cordaites*,

quoted as evidence of rapid elongation, of little or no physiological significance. Abundance of secretory tissue. Anatomical characteristics of a Lepidodendroid type of stem; great development of secondary tissue in the outer cortex, little or no true cork, lax inner cortex. Lacunar tissue in the roots of calamites; hollow appendages of *Stigmaria*. Indications of xerophytic characters may be the result of growth in salt marshes.

Evidence as to the Manner of Formation of Coal.

(*a*) The structure of *calcareous nodules* found in coal seams; the preservation of delicate tissues, the occurrence of fungal hyphæ and the petrification of Stigmarian appendages as evidence in favour of the subaqueous accumulation of the plant-débris found in the calcareous nodules.

(*b*) *Ordinary coal* microscopically examined. Spores, fragments of tissues, bacteria, and the ground substance of coal. Coal found in the cavities of cells in carbonised tissues. Suggested non-vegetable origin of the matrix of coal. 'Boulders' and coal-balls included in coal seams.

(*c*) *Boghead, Cannel coal, and Oil-shales.*—Recent investigations of Bertrand, Renault, and others. The structure and mode of origin of torbanite, kerosene, shale, &c. Suggested origin of Boghead from the minute bodies of algæ (*fleurs d'eau*), spores, &c., embedded in a brown ulmic substance found on the floor of a lake. Absence of clastic material. Cannel coal characterised by abundance of spores.

(*d*) *Paper-coal of Russia.*—The paper-coal of Culm age in the Moscow basin consists largely of the cuticles of a Lepidodendroid plant. Bacterial action as an agent in the destruction of plants and as a factor in the production of coal.

The Origin of Coal. *By* J. E. Marr, *F.R.S.*

I. *What is Coal?* A non-scientific term introduced into scientific nomenclature for substances of divers character and, therefore, probably of different modes of origin.

II. *Was the Carboniferous period one where conditions suitable to formation of coal were unusually widespread?*

Coincidence at this period of dominant giant cryptogams, extensive plains of sedimentation, and suitable climatic conditions. Such coincidence never occurred before or after the Carboniferous period.

III. *What work should be done in order to advance our knowledge of origin of coal?*

In the past light has been thrown on coal-formation by chemical, petrological, palæontological, and stratigraphical studies, and these should be continued.

1. *Chemical.*—Importance of study of chemical composition of fire-clays and other accompaniments of coal in addition to coal itself.
2. *Petrological.*—Dr. Sorby's work on origin of grains of mechanically formed rocks (sandstones, &c.) should be continued.
3. *Palæontological.*—Studies of faunas and floras throwing light on physical and also on climatic conditions.
4. *Stratigraphical.*—Much detailed work is required in many parts of the world to discover over what periods coal-formation occurred in exceptional amount. Tendency at outset to refer all upper Palæozoic coal-formations to the Coal-measures.

The following Papers and Reports were read:—

1. *On the Fish Fauna of the Yorkshire Coalfields.* *By* Edgar D. Wellburn, *F.G.S.*

Only Lower and Middle Measures present; their extent and boundaries. Lower Measures, their extent and general characters, beds of marine and fresh-

water origin present. Middle Measures, their general character; formed in a series of freshwater lake basins. Fish remains, where found and in what state of preservation; their habits of life; Elasmobranchs, Teleosteans (and in some cases Dipnoians), commingled, *i.e.* marine and freshwater types in same beds (freshwater); Elasmobranchs found in marine and freshwater beds; Dipnoi only found under freshwater conditions. Teleostean orders, Crossopterygii and Actinopterygii found in both freshwater and marine beds. Conditions under which coals were deposited as bearing on the occurrence and habits of the fish. The swim-bladder of Cœlalacuthus, and its peculiar use to them under certain conditions. Remarks on fish remains; Elasmobranchii represented by eleven genera and twenty-three species; Ichthyodorulites by seven genera and eight species; Dipnoi by two genera and two species; and the Teleostomi by twelve genera and thirty-three species. Tabular list of fish remains showing their stratigraphical distribution; remarks on above list; several new fish-bearing coal shales; the distribution and vertical range of the Yorkshire coal-fishes being thus greatly extended; several genera and species new to Yorkshire, and others new to science.

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2. *On some Fossil Fish from the Millstone Grit Rocks. By* EDGAR D. WELLBURN, *F.G.S.*

The Millstone Grits are naturally grouped into three divisions, viz.: (1) Rough Rock; (2) Middle Grits; (3) Kinder Grits at base. Middle Grits, consisting of grits, sand, shales, subdivided into A B C and D beds, A being uppermost. Pennine Anticline, mostly composed of these rocks, and on Lancashire side at head of Calder Valley, on the south side in a quarry at summit, there is a good exposure of the D shales, and in these shales majority of fish remains found; a few others having occurred at same horizon at Wadsworth Moor, Sowerby, Kilne House Wood, and Eccup, Yorkshire. Majority of fish in nodular masses, few in shales. Associated with marine fauna. Fish-bearing beds formed under marine estuarian conditions. Fish of great geological and zoological interest, as largely increasing our knowledge of the fish fauna in groups of rocks whose yield of fish remains has hitherto been extremely limited; and zoologically in fact that (1) one genus and several species are new; (2) one Lower Old Red Sandstone fish present; (3) the occurrence of the Lower Carboniferous types, Orodus, Psephodus, Pristodus; and (4) several genera and species are new to these rocks. Remarks on fish remains. Table of stratigraphical distribution.

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3. *The Plutonic Complex of Cnoc-na-Sroine and its Bearing on Current Hypotheses as to the Genesis of Igneous Rocks. By* J. J. H. TEALL, *M.A., F.R.S., Pres.G.S.*

The plutonic complex of Cnoc-na-Sroine begins about five miles south of Inchnadampf, in Sutherlandshire, and extends in a south-easterly direction for about five miles, with an average width of about one mile. It is bounded on the north and south by peat-covered tracts, and is, therefore, more extensive than is indicated by the above figures. It lies in the disturbed zone. The main outcrop of the Ben More thrust lies to the east, but outliers of rocks above this thrust occur to the north and west. The plutonic rocks were intruded into the Durness limestone series, which is locally altered at the junctions to a marble containing silicates of lime and magnesia.

The central part of the mass is a red soda-granite or quartz-syenite,[1] mainly composed of orthoclase and albite (or a closely allied felspar), with which a little quartz is associated. Ferro-magnesian minerals are almost entirely absent. The peripheral portions are more basic, and include syenites, augite-syenites, nepheline-

[1] See *Geological Magazine* for September, 1900, for further petrographical details.

syenites, and the peculiar rock to which the term borolanite has been applied. These basic border rocks are richer in lime, iron, magnesia, and titanic acid, though still containing alkali felspar and nepheline. This is proved by the occurrence of biotite, ægirine-augite, melanite, and sphene.

There are three possible ways in which the complex may have originated: (1) successive intrusions; (2) differentiation *in situ*; and (3) modification of the original magma by the absorption of material from the adjacent limestones or dolomites.

The fact that transitional forms between the main types are abundant seems to suggest that successive intrusions of sharply differentiated magmas have not played an important part in the building up of the complex. The formation of a border facies of basic rocks, richer in lime and magnesia, can be explained by absorption from the adjacent limestones or dolomites, but the enrichment in iron and titanic acid, as represented by the frequent abundance of melanite and sphene, cannot be so accounted for. The evidence at present available suggests that differentiation, coupled, it may be, with some absorption of material from the adjacent sedimentaries, has been the main agent in forming the complex.

But, however the complex may have originated, it is certain that the magmas representing the more acid and the more basic portions appear outside the plutonic area as dykes and sills. Thus to the north there are felsitic rocks containing ægirine closely allied in composition to the quartz-syenites, and in the Coigach district of West Ross-shire, about seventeen miles to the west of Cnoc-na-Sroine, there are dykes of borolanite.

The main object of this communication is to call attention to the extremely interesting petrographical province—unique so far as the British Islands are concerned—of which Cnoc-na-Sroine forms a part, and to the problems connected with it which still await solution.

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4. *On a Granophyre-dyke Intrusive in the Gabbro of Ardnamurchan, Scotland. By* Professor K. Busz, *of Münster.*

Similar contact-phenomena to those already known of Barnavave in Ireland and of Strath on the isle of Skye have been found near the village of Kilhoan on Ardnamurchan, where a granophyre-dyke, intrusive in a surrounding mass of gabbro, has not only effected alterations of the gabbro, but has also undergone alterations in its own composition through the absorption of basic material.

The gabbro occurs in two varieties, the one being a fine sugar-grained black rock, without any macroscopically visible structure, the other showing a porphyritic structure and containing small black crystals or crystalline aggregates of triclinic felspar.

They both consist of anorthite, pyroxene—diallage and common augite—and magnetite; rhombic pyroxene in considerable quantity is also present in the porphyritic variety.

On the junction line, where the granophyre and gabbro meet, all constituents have been greatly altered. The triclinic felspar gradually passes into orthoclase and the alteration-product of pyroxene is hornblende (usually uralite), brown mica, and secondary granular augite.

The granophyre consists of quartz generally in well-defined crystals and of grey orthoclase, which serves as interstitial matter. It also contains a great number of rectangular felspar crystals, the centre of which in many cases consists of triclinic felspar (gabbro-xenocrysts). It appears spotted with numerous black patches of different size, mostly minute, which are the remains of pyroxene-xenocrysts, originated from the gabbro and showing every stage of alteration.

The results of the examination of these rocks lead to the following conclusions:

1. The gabbro is presumably a dyke-rock, belonging to the group which has been termed *beerbachite*, and also partly a porphyritic variety of the same—*beerbachite-porphyry*.

2. It was solidified before the intrusion of the granophyre, as the latter contains

a great number of xenoliths of it, which through the acid magma have undergone great alterations.

3. The granophyre has absorbed a considerable quantity of the basic material, thereby altering its own composition and effecting the crystallisation of hornblende and mica, two constituents which we have to consider as not belonging to the original granophyre magma.

4. In the solidification of the granophyre two stages can be distinguished, the first giving rise to the formation of the rectangular orthoclase crystals, which crystallised in parallel intergrowth with the plagioclase-xenocrysts, the second forming a kind of groundmass in which fresh quartz crystallised, while the orthoclase filled up the remaining spaces.

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5 *Interim Report on the Present State of our Knowledge of the Structure of Crystals.*

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6. *Report on Life Zones in British Carboniferous Rocks.*
See Reports, p. 340.

TUESDAY, SEPTEMBER 11.

The following Papers and Reports were read:—

1. *On* Naiadita *from the Upper Rhætic (Bed K of Wilson's Section) of Redland, near Bristol. By* IGERNA B. J. SOLLAS, *B.Sc.*

The plant remains known as Naiadita are found in Rhætic beds in the Severn district below the Avon. Phillips mentions their occurrence at Tewkesbury, Westbury-on-Severn, and Bristol.

These fossils are well known from the description published fifty years ago by Buckman. It was Buckman who chose for them the name Naiadita, because he considered them to be monocotyledonous plants resembling the members of the order Naiadaceæ.

Mr. Starkie Gardner in 1886 re-examined them, and pointed out that the markings taken by Buckman as having been left by the rectangular venation of a Naias-like leaf were in reality fossilised cell-walls.

Mr. Gardner concludes that the plant is a moss, and probably closely allied to the genus Fontinalis. He speaks of a capsule, but of this he gives no description.

A slab from the Naiadites bed of Pyll Hill, Bristol, was recently sent by Mr. Wickes of that town to my father for examination, because it contains bodies which were thought to be possibly gemmules of sponges. On this proving not to be the case the specimen was handed over to me.

The plant, which was delicate, slender, and moss-like in habit, is preserved in a more or less fragmentary condition. I believe, however, that the parts are sufficiently connected to show that the sporangia are situated at the bases of the leaves, between their upper surfaces and the stem. The stems branch laterally, and a sporangium is often to be seen near a point of branching.

The shapes of the leaves are various, and this has led Buckman to establish three distinct species. No doubt there may be more than one species present, but certainly leaves of at least two different shapes are to be seen attached to one and the same piece of stem, viz., small obovate leaves and larger ones of an elongate elliptical shape.

The epidermal cell-walls are preserved and their outlines are very clear. The cells are long and rectangular, shortening towards the bases of the leaves. No stomata are to be seen.

The capsules are more or less spherical, and measure 0·75 mm. in diameter. Those which are broken are seen to contain a granular mass of spores. The more perfect capsules have a wall which appears tessellated, as it is composed of small quadrate cells.

Sections of the capsules show that the spores are still connected into tetrads by the spore mother cell-walls. The coats of the spores are covered with minute bosses. The sporangium wall is at least one cell layer thick.

Sections of the vegetative parts do not reveal any details of structure, but some points may be made out by simply rubbing down on a hone. Long tubes filled up with oxide of iron lying in the axes of the stems are all that is preserved of the internal tissues. The tubes may occasionally be found sending a branch to a leaf.

The nature and position of the sporangia and their contents suggest that Naiadita had affinities with Lycopods rather than with mosses.

On this account I searched thoroughly for stomata, as structures confirmatory of the sporophytic nature of the plant. The result of the search was, as I have said, negative, and it is not surprising that this should be the case. The associated fossils are freshwater forms, and the habits of the plant point to a submerged existence. Mr. Gardner has already appreciated this fact in maintaining the close kinship of Naiadita with Fontinalis. The submerged species of Isoëtes show that aquatic life in the case of Cryptogams leads to loss of stomata just as in that of Phanerogams.

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2. *The Influence of the Winds upon Climate during Past Epochs: a Meteorological Explanation of some Geological Problems. By* F. W. HARMER, *F.G.S.*

This paper is in continuation of one read at Dover in 1899, on 'The Meteorological Conditions of North-western Europe during the Pliocene and Glacial Periods.'

The irregular distribution of the isotherms in the northern hemisphere is largely due to the direction of the prevalent winds. In regions where these are constantly varying, as, for example, in Great Britain, the climate varies diurnally, one day being often dry or cold, and the next rainy or warm. In others, where the wind changes seasonally, one part of the year is rainless and another pluvial. Permanent alterations in climate would equally result were the course of the prevalent winds permanently changed.

The direction of the winds, which must always be more or less parallel to the isobars, depends on the relative position, and on the form and alignment of areas of high and low barometric pressure. The movements of the latter being largely interdependent, any important meteorological disturbance, however caused, may make its influence felt at a considerable distance from the focus of its origin.

The winds blow round areas of high and low pressure; outwards, from the former, and to the north of the Equator, from left to right; and inwards, towards the latter, from right to left. Hence, in the northern hemisphere, southerly winds prevail to the east of a cyclonic centre, and northerly winds to the west of it, the contrast between the temperature of the two being usually in proportion to the distance the aërial currents may have travelled from the south and the north respectively. Warm and cold winds must therefore necessarily coexist, causing differences in climate in countries having the same latitude. The winter temperature of Hudson's Bay is, for example, 60° F. colder than that of Great Britain. Similar climatal conditions must also have existed during the Pleistocene epoch.

The continental regions of the northern hemisphere, being at present warmer during summer than the ocean, are cyclonic; in winter they are colder, and consequently anticyclonic. Over the great ice-sheets of the Glacial period, however, high pressure must have prevailed, more or less, at all seasons, and, generally, the meteorological conditions, including the direction of the prevalent winds, and local variations in climate must then have been widely different from those of our own

times. Oceanic winds, with copious rainfall, may have prevailed in regions now arid, and mild winters where they are now excessively severe. Such cases of anomalous climate as those of the pluvial conditions of the Sahara, and of Arabia and Persia, during the Pleistocene era, may be satisfactorily explained by the changes in the relative positions of cyclonic and anticyclonic systems, which were caused by the gradual growth and disappearance of the great ice-sheets, as may be the alternate humidity and desiccation of the great basin of Nevada, the former existence of the mammoth on the shores of the Polar Sea, &c.

It is difficult, however, to restore hypothetically the meteorological conditions of the Pleistocene epoch, on the theory that the maximum glaciation of the eastern and western continents was contemporaneous. At present, the influence of the Gulf Stream and the south-west winds caused by the Icelandic cyclone carries in winter a comparatively warm climate, and low pressures, northwards into the Arctic Circle, but no permanent ice-sheet could have existed in Great Britain under such circumstances. In the opinion of Professor Jas. Geikie and of Dr. Buchan, the polar basin was filled with ice, and therefore permanently anticyclonic, during the Glacial epoch. Cyclones and anticyclones in regions more or less contiguous are, however, necessarily complementary, in order that the vertical circulation of the atmosphere may be maintained. The existence of an enormous polar anticyclone, extending southwards over a great portion of Europe and North America, would have involved also that of a cyclonic system of corresponding importance in the North Atlantic, a region which must have been at all seasons warmer than those covered with ice. If Europe and North America were glaciated at the same time, the Icelandic cyclone, which now lies (statistically) in winter near to the south-east coast of Greenland, would have been forced to the south; but the further south it went, the warmer would have been the southerly winds which blew east of its centre towards Great Britain and Western Europe. Conditions similar to those which may have prevailed during the Glacial period occurred during the early part of 1899, for information as to which the author desires to acknowledge his indebtedness to Mr. W. N. Shaw, F.R.S., of the Meteorological Office. At that time a great low-pressure system, which sometimes extended from Europe to America, and from Iceland to the Canary Islands, occupied the North Atlantic. Vast volumes of cold air were consequently poured over North America, and Western Europe was flooded by warm aërial currents from the sub-tropical zone. At the beginning of February, temperatures of from $-40°$ F. to $-60°$ F. were commonly registered in different parts of North America; while at the same time the thermometer rose in London to 66° F., in Liège to 70° F., and in Davos to 62° F., the average maximum for that month at the latter place being 38° F. These coincident variations in the temporary climate of the northern hemisphere are directly traceable to the same cause.

No meteorological difficulties arise if we adopt the hypothesis that glacial and interglacial periods alternated in the eastern and western continents. If the ice-cap extended from Greenland to Scandinavia, the North Atlantic cyclone would have been forced to the south-west, towards the American coast, producing warm south-east winds over Labrador; if, on the contrary, it stretched from Greenland to North America, the cyclone would have been driven in the direction of Europe, causing mild weather in the latter, as in the case just given.

Such a view affords a simpler explanation of the geological facts than those usually adopted. Instead of supposing that the climatic changes of the Great Ice age, several times recurrent at intervals of a few thousand years only, were due to astronomical causes, it is here suggested that the climate of the Pleistocene epoch being uniformly colder than that of our own era, conditions of comparative warmth or cold may have been local, as they now are, affecting the great continental areas at different periods.

3. *Notes on some Recent Excavations in the Glacial Drift in Bradford. By* Jas. Monckman, *D.Sc.*

The stream that flows through the Bradford Valley rises on the hills above Thornton and flows in an easterly direction to the centre of the town, where it turns at right angles towards the north and falls into the Aire at Shipley.

In the lower branch of the valley we find abundance of glacial materials, which have been pushed up from the Aire by a branch of the Airedale glacier, and among the rocks abundance of limestones.

In the upper valley we do not find the same state of things; but, instead of the limestones, are grits and sandstones, except along a line commencing at Leventhorpe Hall (which is about three miles from the centre of the town), and passing through Lidget Green, Grange Estate, Little Horton to Bankfoot, it forms a fairly straight line, about three-quarters of a mile south of the Town Hall, at its nearest point.

Behind Grange Road, to the south, there is an extensive deposit, which has been exposed to a depth of twenty-two feet in some places, and excellent opportunities afforded of examining the boulders, among which were found many specimens of limestones, light-coloured and dark, banded and cherty, also a fair quantity of Silurian grits.

I afterwards found limestone at Hewenden, and Mr. Muff found it near Oxenhope; there is also an immense deposit at Cowling.

Thus we find the same kind of deposits along a moderately straight line on the south side of the Aire Valley.

The presence of the Silurian pebbles appears to indicate that, as there is no rock on the south of the Aire from which they could be derived, the Ribblesdale ice was forced over into Airedale, and that the moraine formed from the grits and slates of Ingleborough became the southern one in the Aire Valley.

The grit boulders to the south of this line are of the same character as the strata forming the hills on that side of the valley, and were probably carried by smaller local streams of ice.

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4. *On a Glacial 'Extra-morainic' Lake occupying the Valley of the Bradford Beck.* By J. E. Wilson.

In the paper read by the late Professor H. Carvill Lewis before the Geological Section at Manchester in 1887 on the Extra-morainic Lakes of Central England and elsewhere, he pointed out that the Aire glacier was the cause of three lakes—one in the neighbourhood of Skipton, towards Bolton Abbey; one due to the damming up of the Bradford Beck; and one in the valley of the Worth. The present paper is the outcome of an endeavour to verify these observations of Professor Lewis. The proof of the existence of the Aire glacier and of its extension need not detain us further than to point out out that glacial striæ occur on both sides of the Aire Valley, and are seen about the outlet of the Bradford Beck at Windhill, and that boulder clay containing scratched limestones is frequent in the Bradford area. Any glacier in the Aire Valley which extended on to the slopes of Idle Hill, the northern point of the ridge which bounds the Bradford basin to the east, would block up the mouth of the Bradford Valley. This ridge has an altitude above the sea at Idle Hill of 750 feet, and gradually decreases in height as far as Laisterdyke, afterwards rising again to the southward. The lowest point of the lip of the Bradford basin is marked by the dip through which the Great Northern Railway extends out of Bradford at Laisterdyke. In the event of a block in the valley between Heaton and Idle Hill this would naturally be the outlet of the lake so produced. The height of the col at Laisterdyke is about 560 feet above the sea.

It would be very unlikely that one would find in a district like this, either much built over or under cultivation, anything in the way of beaches or terraces. But at several points beds of sand and sandy clay have been observed, and these occur at levels of about 550 feet. The most striking is a deposit of sand and silt, showing extremely good current-bedding, on the hill opposite Leaventhorp Mill, towards Allerton, and also in the neighbourhood of the mill itself. The mode of its occurrence and its appearance suggest a delta deposit, and it is at exactly such an altitude as would fit with the presence of a lake having an outlet at Laisterdyke. The difficulty occurs, however, that the stream flowing in the valley separating the two patches of current-bedded material has a much smaller drainage

area than Thornton Beck, of which it is a tributary, and in the Thornton Beck Valley similar deposits are very poorly represented.

To explain this a consideration of the lakes to the westward is necessary. Although Professor Carvill Lewis only inferred lakes in the Bradford area and in the Haworth area, there is a valley—that of the Harden Beck—between them, which also maintained its lake. The Chellow Dean reservoirs of the Bradford Corporation are situated in a deep narrow valley, the rivulet originally flowing down it having its rise in a drainage area of only about three-quarters of a mile square, an area wholly inadequate to account for the valley. Its upper part is in fact a deep notch in the ridge, which would form the outlet of the Cullingworth lake, and is at a height of 720 feet. The presence of this lake would account for beds of current-bedded silt at Sandbeds, near Cullingworth, at exactly this level. But in the valley below Chellow Dean hardly any traces of delta deposits have been observed at the level of Lake Bradford—that is, on the same level as the Leaventhorp beds. If, however, the extension of the Aire glacier blocked up the notch at Chellow Dean, the outlet of the lake would be at the next lowest col—that near Stream Head Farm, 870 feet above the sea. The valley below Stream Head Col soon becomes a deep narrow gorge similar in many respects to that at Chellow Dean, and it is on either side of this valley, when it reaches the level of Lake Bradford, that the delta deposit above referred to is found. The position of this large deposit would therefore be explained if it is regarded as the result of the erosion of the valley above by the water from the extensive drainage areas of the Worth and Harden Beck pouring over the Stream Head Col. The material carried down by the beck and arrested in its course on reaching Lake Bradford would be deposited just where the Leaventhorp beds occur. Corroborative evidence of the presence of a lake at the level of the Stream Head Col is possibly provided by the occurrence of current-bedded sand exposed in a gravel pit at Hallas Rough Park at about the level of the col.

On the other hand, the absence of delta deposits from the Chellow Dean Beck would be explained if it is considered that possibly, when the extension of the glacier was such that the Chellow Dean Col was open, the size of the glacier was not sufficient to wholly block the mouth of the Bradford Valley. In this case the water would escape by its present outlet, and no lake would exist to arrest the material brought down from the ravine of Chellow Dean.

At the period when the Chellow Dean Col was open there would be two lakes to the westward, one in the Cullingworth Valley, above mentioned, and one in the Worth Valley. The outlet of the latter would be a deep notch at Sugden End, near Haworth, at 720 feet; but as the Stream Head Col is at a greater height than this, the two lakes would be merged into one large lake when the Chellow Dean Col was blocked, so that for this period Professor Carvill Lewis's theory would be correct.

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5. *A Preliminary Note on the Glaciation of the Keighley and Bradford District. By* ALBERT JOWETT, *M.Sc., and* HERBERT B. MUFF.

1. *General View of the Surface Features of the Area.*

The general trend of the Aire Valley in this district is from N.W. to S.E. Actually, the valley makes a number of roughly rectangular bends, receiving a large tributary valley, from the south side, at each southern convexity, viz.: the Glusburn Valley at Kildwick, the Worth Valley at Keighley, the Harden Valley at Bingley, and the Bradford Valley at Shipley. The valleys entering on the north side are much smaller.

The tributary valleys, of which the Worth Valley and the Bradford Valley are the largest and most complex, have been excavated in the plateau of Upper Carboniferous rocks, of which the Millstone Grit here forms the Pennine watershed. The altitude of the watershed rarely exceeds 1,500 feet; there is a break below 1,125 feet west of Haworth, and a broader depression below 900 feet between Colne and Kildwick. The ridges between the tributary valleys, on both

sides of the main valley, are cut at right angles in many places by notches trending from N.W. to S.E.

2. *Characteristics of the Glacial Deposits and Striæ.*

Boulder Clay is found in many places throughout the area, and consists of a tough blue clay which has a superficial covering of yellow sandy clay of very variable thickness. The contained stones are chiefly Carboniferous limestone, chert, grit, and sandstone, including gannister, together with shales and ironstone nodules. Occasional pre-Carboniferous grits and slates have been met with. The limestone boulders become fewer in number and generally smaller in size as we proceed down the main valley, and also as we approach the periphery of the area from the main valley. Boulders of the other rocks are also found to the south-east of their solid outcrops. Most of the boulders in the blue clay are beautifully moulded and striated. The yellow clay contains fewer limestones than the blue, of which it appears to be simply the weathered crust.

Gravel is often found above and at the margin of the boulder clay, and in some places passes into current-bedded sands. Occasionally a section is seen showing clay, sand, and gravel of all degrees of coarseness in interdigitating layers. Sections at the lower ends of the spur-cutting notches above mentioned have revealed current-bedded sands and gravels, &c., composed of materials similar to the rocks exposed in the sides of the gorge above. Striæ are most frequently preserved on beds of grit which have a covering of clay; one set was found on gannister similarly preserved. In the case of the grit surfaces, not only are there long parallel striations on the whole surface, but the larger quartz-pebbles are very finely scratched in the same direction. The direction of the ice-movement was deduced from the observation that surface irregularities were rounded and smoothed on the one side, but rough on the other.

3. *Maximum Extent and Direction of Movement of Glacier.*

The floor of the Glusburn Valley is covered with boulder clay which is continuous with and similar to the drift on the western side of the Pennine watershed described by Mr. R. H. Tiddeman. On Cowling Moor, a long ridge of unstratified gravel, 50 feet thick, is seen at an altitude of 1,150 feet O.D. Great masses of a hard conglomerate of limestone, grit, and shale occur, the cementing material of which is calcite, evidently deposited from solution by percolating water. Above this ridge, sandy clay with limestone and chert, as well as grit, gannister, &c., may be traced up under the peat to 1,350 feet, and to a somewhat greater altitude to the westward. Combe Hill (1,454 feet) was not overrun by the ice, its surface being covered by the angular fragments of the underlying grits, and drift being also absent from its southern and south-eastern slopes. On Boulsworth Hill, to the south, drift is found up to nearly 1,400 feet. Thus, though the ice stood up against these two hills, it did not actually force its way through the gap between them.

Traced eastwards, the altitude of the margin of the drift diminishes, and it continues to diminish all down Airedale. It reaches 1,250 feet on Keighley Moor, and is traceable round into the Worth Valley above Ponden at 950 feet. On Haworth Moor the limit is met above Leeshaw Reservoir, and south-west of Leeming, at just above 1,025 feet. No traces of glaciation occur on Oxenhope Moor and Thornton Moor above Denholme; but the ice pushed round into the Harden Valley, leaving a marginal moraine at Hallas Rough Park (900 feet) consisting of boulder clay, gravel, and sand heaped up in ridges running from N.W. to S.E. The Harden Valley contains boulder clay as far as Denholme Station. Clay is also found in the Wilsden Valley and up the face of Harrop Edge to over 925 feet. Drift around Allerton shows that the ice pushed over Chellow Dean into the Bradford Valley, laying down thick deposits of tough clay, with many scratched limestones at Horton Grange, and reaching up to the summit of the ridge separating Airedale and Calderdale at Wibsey Bank Foot. The drift-filled valley seen in section near Low Moor Station points to the conclusion that, at the extreme

phase, a lake of ice actually stood over the broad depression in the watershed there, and smeared over the low slope a thin cover of boulder clay which entirely obliterated the pre-existing minor surface features.

The presence of drift brings the ice-edge far up the slope as we follow the watershed round past Bowling to Laisterdyke, where the ice laid down in a hollow in the solid rock, outside the Bradford Valley, a mass of clay 70 feet in thickness. The country east of Tyersal is driftless, but the ice passed over the ridge from Undercliffe to Wrose Hill, boulder clay occurring on the top of Stonehall Hill, Eccleshill, at an altitude of 700 feet, and also all along the eastern slope of the ridge. The altitude gradually drops as far as Newlay, where a mass of gravel 30 feet thick occurs at 200 feet O.D., and 75 feet above the level of the river. All the pebbles are rounded, and though limestones are numerous, they are small in size, rarely exceeding four inches in diameter. This gravel marks the last definite trace that we have found in Airedale of the Airedale ice.

From similar evidence to that which we have adduced in the case of Airedale, we conclude that there was a glacier in Wharfedale which was confluent with the Airedale Glacier to the N.W., and also to the S.E. of Rumbles Moor, leaving only its highest ridge uncovered as a 'nunatak.' The limiting altitude of the ice on the west is 1,250 feet, sinking gradually to about 1,100 feet on the east. The configuration of the country, and the presence of a series of drift ridges running continuously from Wharfedale on the N.W. to Airedale on the S.E., lead us to believe that the Wharfedale Glacier pushed in as far as Guiseley, the onset of the Airedale Glacier having been considerably weakened here by its passage over Hope Hill and the high ground between Hope Hill and Rumbles Moor. The outermost of these ridges consists largely of gravel containing limestones, and runs from Lanshaw Delves, on Ilkley Moor, to Hawksworth.

Over the districts of Guiseley, Yeadon, and Horsforth, drift occurs sporadically, and we have been unable to draw a boundary line between the Airedale and the Wharfedale ice in this region.

The striæ indicate a general ice-movement from the N.W. Those which we have observed at higher levels are more strictly parallel to this general direction, whilst the others more nearly conform with the trend of the particular part of the valley in which they occur. A greater freedom of movement would be expected in the upper layers of a glacier than in the lower layers, which must mould themselves to the inequalities of the glacier bed.

The whole area, within the limits traced out above, displays abundant evidences of the characteristic remains of a glacier. From Apperley Bridge upwards the lower portion of the main valley is full of moraine mounds left behind during the retreat of the ice. The best examples are at Tong Park, near Esholt; Nab Wood, near Saltaire; and Bingley.

4. *The Extra-Glacial Drainage.*

Every embayment in the unglaciated area—at the edge of the ice at its greatest extension, and during the various phases of retreat—would, by receiving the natural drainage, be converted temporarily into a lake. The level of each lake would be determined by the height of the ice-barrier and of the watershed around the margin of the lake. The height of the ice-barrier becomes gradually lower from N.W. to S.E., and hence we should expect the level of each succeeding lake at some particular phase to be lower than that of the lake preceding it to the N.W., so long as the drainage water is confined on that side of the main watershed proximal to the ice.

We should therefore expect an overflow of the waters of each lake, by the lowest point in its margin, into the succeeding lake at the period of greatest extension of the ice and at every other temporary stationary period during the general recession.

The peculiar spur-cutting valleys above mentioned we believe to have been the overflow-channels of such lakes. Typically, they are flat-bottomed, steep-sided grooves passing completely through the watershed, characters indicating rapid cutting by considerable volumes of water. They often end quite suddenly

on both slopes of the watershed through which they are cut, with no approach to base-levelling to the existing streams. They all slope from the west or north-west in an easterly or south-easterly direction, their lower terminations being often marked by level or gently sloping fans of detritus. The altitude of such an alluvial flat corresponds with that of the head of a similar valley on the next spur to the south-east. The very temporary nature of the surface levels of the lakes, as attested by the rapidity with which the gorges were cut, renders the production of beaches similar to those observable in Glen Roy and neighbourhood very unlikely. We have not found any but doubtful examples; the detection of such minor features in a country consisting of nearly horizontal beds of hard sandstone and soft shale must ever be a matter of extreme difficulty.

A list was brought forward of over forty overflow-channels with their altitudes, which mark the successive levels of the surface-waters of the lakes. During the maximum glaciation there were six lakes on the south side. Those on the north side were only in existence during retreat.

The authors desire to thank Mr. P. F. Kendall, F.G.S., for much valuable advice in connection with the extra-glacial drainage systems.

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6. *The Source and Distribution of the far-travelled Boulders of East Yorkshire.* *By* J. W. Stather, *F.G.S.*

About ten years ago Mr. G. W. Lamplugh counted and roughly classified the larger boulders of Flamborough Head and other selected localities on the Yorkshire coast. The work has been continued by the members of the Hull Geological Society, who have examined and tabulated upwards of 3,500 boulders of 12 inches and upwards in diameter (the size-limit adopted by Mr. Lamplugh).

But besides the larger boulders attention has been paid to the smaller stones of the drift, which have also yielded results of much interest.

With regard to the larger boulders (lists of which have been published in the reports of the Yorkshire Boulder Committee and of the British Association Committee) it has been sought to discover the proportion of rocks from distant sources, after the elimination of the secondary rocks of local derivation.

The following table, showing the boulders of two selected localities in the southern part of the Yorkshire coast and two in the northern part, will serve to illustrate the general distribution:—

—	Dimlington	North Ferriby	Whitby	Saltburn
	per cent.	per cent.	per cent.	per cent.
Carboniferous sandstones and limestones	55	59	70	73
Basalt (whin-sill)	32	30	24	20
Granite, gneiss, &c.	13	11	1	0
Magnesian limestone	—	—	5	7
	100	100	100	100

The investigation shows—(1) The proportion of Carboniferous sandstones and limestones increases northward. (2) The whin-sill increases southward proportionately though not numerically, probably bearing transport better than (1). (3) The magnesian limestone in the form of *large* boulders disappears southward. (4) The granites, gneisses, &c., decrease both proportionately and in numbers northward, except the Shap granite and the Cheviot porphyrites, which show a rapid increase in the same direction. A considerable number of (4) agree with well-known rock types of Scandinavia, and these are more plentiful in the south of the county and in Lincolnshire than in North Yorkshire. The unknown rock types included in the same group agree in this respect with these recognisable Scandi-

navian rocks, which bears out Mr. Harker's suggestion that the rocks not identified are also from Scandinavia.

The distribution of the Cheviot porphyrites, which occur principally as stones and pebbles of smaller dimensions than the boulders of the above table, presents some points of peculiar interest. These, besides increasing in numbers towards their source, are also more abundant in the upper boulder clays and in the gravels at the highest levels than in the low-level drift; while, on the other hand, the Scandinavian rocks, whether as pebbles or boulders, rarely occur at high levels. This lends support to Mr. Lamplugh's supposition that the North Sea ice-sheet attained its maximum development and reached farthest inland before the ice flowing from the north-west of England had reached this portion of the coast, and that the former flow shrank back as the latter gained strength.

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7. *On the Glacial Phenomena of the North-east Corner of the Yorkshire Wolds. By* J. W. Stather, *F.G.S.*

The rapid thinning away of the Drift inland from the Yorkshire coast has long been recognised and variously explained. The phenomena along the margin where it thus thins away on the high ground are worthy of particular attention.

North-westward from Speeton, where the drift terminates in a chain of morainic mounds, the top of the chalk escarpment is more or less covered with drift as far as Hunmanby, where a deep valley, now dry, breaks through the escarpment, and drains inward to the central valley of the Wolds. Into the valley at Hunmanby the drift penetrates for a considerable distance, in the form of boulder clay on the slopes, and gravel containing many foreign stones in the bottom. The boulder clay thins out long before we reach the main valley, but the gravel with foreign stones intermixed with local material is present in strong force in the bottom of the main valley, and it is suggested that a stream draining from the ice has flowed from Hunmanby along this course. In the higher parts of the main valley, above Weaverthorpe, foreign material is almost absent, except that near the head of the valley, near Luton, there is a patch of drift (shown on the Geological Survey map) in which are foreign stones, derived chiefly if not wholly from the oolitic rocks, quite different from the drift in the lower part of the valley.

North of Hunmanby, at the sharp angle of the Wolds, the boulder clay again rises to the crest of the escarpment in the form of a thin covering which fades out gradually westward into a sprinkling of foreign stones in the soil. The stones occur abundantly at an altitude of 400 feet above sea level at High Fordon and include a large number of Cheviot porphyrites, which here as elsewhere further north are most abundant at the highest levels, near the margin of the Drift.

To explain these phenomena it seems necessary to suppose the existence of an ice-sheet occupying the bed of the North Sea, with its margin only slightly overtopping the Wolds and not extending far across them. It also appears, as stated in a preceding paper, that the ice carrying the Cheviot rocks formed the uppermost portion of the sheet.

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8. *On the Age of the Raised Beach of Southern Britain as seen in Gower. By* R. H. Tiddeman, *M.A., F.G.S., H.M. Geological Survey.*

[Communicated with the permission of the Director-General.]

Gower has a reputation for its caves with their bone-beds, and for its raised beaches, but to the matter of its Glacial Drifts very little attention has been paid.

Some of the caves were known to and noted by Dean Buckland.[1] The caves were long and diligently explored by Colonel Wood of Stout Hall, and the results carefully collated by Dr. Falconer.[2] A great number of the bones are exhibited in the Swansea Museum. Mr. Starling Benson, who lived at Swansea, has left an

[1] *Reliquiæ Diluvianæ.*
[2] Falconer's *Palæontological Memoirs,* vol. ii.

account of Bacon Hole, and Dr. Falconer has incidentally alluded to other caves in describing the animal remains.

These three observers noted the fact that the cave fauna, which included *Hyæna*, *Elephas antiquus*, and *Rhinoceros hemitœchus*, was found in bone-beds in the shore caverns and rested on or above a cemented shelly conglomerate, which was evidently a raised beach, for it formed a floor across the cave at from 10 to 30 feet above the level of the present beach. This conglomerate was found to contain shells which could not be distinguished from those of the litoral zone on the present beach.

It was recognised that the beach must have been made when the sea was at that higher level, and that the bones could not have been accumulated until the coast had been raised above the old beach-level. But the further reasoning, which was chiefly concerned with the age of the bones, was that, the beach being evidently rather recent, the bones must be more recent. Falconer did not appear quite content with this, and called in Prestwich to assist in finding out what relation, if any, the bone-deposits and raised beach bore to the Glacial deposits.

Prestwich appears to have worked from the west along the coast to Bacon Hole, but not to the east. He reported: 'With respect to the point I had particularly in view, viz. the relation of the Gower caves to the Boulder Clay, I am as yet unable to form a decided opinion. I got the Boulder Clay within a mile of the raised beach, but on opposite sides of the Point of Rhos-sili the subject requires further and more lengthened inquiry.' On this Falconer summed up as follows:—

1. That the Gower caves have probably been filled up with mammalian remains since the deposition of the Boulder Clay.
2. That there are no mammalian remains found elsewhere in the ossiferous caves of Britain referable to a fauna of a more ancient geological date.

It is very singular how near these two eminent men were to making a discovery which they were even looking for. To the east of the rich colony of caves between Minchin Hole and Bacon Hole, at which they were specially working, the Drift-beds come on in force, and the succession which they were looking for might have been very well seen.

It is true that the proper succession was gradually hammered out by explorations in other places by the Victoria Cave Exploration Committee, by the late Dr. Hicks in the caves of North Wales, and at a later date by the Rev. C. H. Pollen, but their researches and the facts evolved by them received a long and well-sustained fire of hostile criticism which has not long come to an end.

The survey of Gower has now established, I think I may say, incontestably:—

1. That the raised beach is Pre- or Interglacial.
2. That the bone-beds which rest upon it in the caves are continuous with the earlier 'head' or débris which lies above it along the coast, and which consists of limestone fragments.
3. That Glacial Drift again lies over this.
4. This in turn is often covered by a later deposit of 'head.'

Frequently, immediately above the raised beach is a deposit of sand which is probably blown sand. It contains in places land-snails which are abundant on the blown sands of Glamorganshire. It is of a foxy-red colour, and its lower part is often cemented together into calcareous concretions containing little nodules of manganese and iron. This sand is interesting in this way, that it is seen in many places where sand could not blow now. The upheaval of the coast implied by the raised beach would necessarily subject a wide fringe of foreshore to the action of sun and wind, and the blown sand would result. It is just where we might reasonably expect it.

The section is not always complete. Sometimes the Drift is absent, sometimes it rests on rock, sometimes one member is absent, sometimes another, but this represents the succession in which they always occur when present. It is astonishing how very regular they are, considering the steep irregularity of the cliffs and coasts.

It will of course be suggested that the Drift may have slipped down from the cliffs above on to the 'head.' This hypothesis is fairly negatived by the very strong contrast in material between the 'head' and the overlying Drift. The latter is full of rounded stones of Carboniferous sandstone and Old Red pebbles and fragments, with scarcely a trace of limestone, whilst on the contrary the underlying débris contains nothing but fragments of limestone. The change is exceedingly sudden, and forbids the possibility of the Drifts resting on the cliffs for long previously and later slipping down on to the débris. Scattered boulders would certainly have occurred in the débris.

The Drift is evidently the ordinary Glacial Drift of Glamorganshire, such as abounds further to the north-east, nor can we doubt that it is about the same age as that which sealed up in the Victoria Cave at Settle, and other caves, the fauna which has been so abundant in the caves of Gower, a fauna which if not Preglacial was certainly Interglacial.

On the other hand, the discovery of the antiquity of the raised beach, which does not appear to have been even hinted at, is one which, from the wide range of that physical feature, must necessarily be of importance. It will assist in building up the relations of late formations to the Glacial Period into a consecutive system and establish relations with other successions in lands to which Glacial phenomena have not extended.

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9. *Report on the Erratic Blocks of the British Isles.*

See Reports, p. 343.

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10. *A Ferriferous Horizon in the Huronian, North of Lake Superior.*

By Professor A. P. Coleman.

The Huronian of Ontario has long attracted attention for its geological interest, and also because it is much the most important formation in the Province for its economic products, most of the mines of gold, copper, nickel, and iron occurring in it. There has, however, been much difficulty in correlating the different areas mapped as Huronian, and doubts have been expressed as to their being of the same age. The finding, a year ago, of a band of iron-bearing sandstone and jasper in the Michipicoton district, north-east of Lake Superior, has thrown fresh light on the subject. This band has already been traced sixty miles, and very similar rocks have been proved to exist at various points for a distance of 600 miles, practically from one end of the Province to the other. Not far off from this band there are very often thick beds of schist conglomerate containing pebbles of the ferriferous rock, indicating a profound break between upper and lower Huronian. These two easily recognised horizons occur in practically all the Huronian areas of Ontario, and afford an excellent clue to the stratigraphy. Their equivalents are probably found in the Vermilion iron range of Minnesota and the Markette and Penokee ranges in States to the south of Lake Superior, containing the most famous iron mines in America. One similar mine has been found at Michipicoton, estimated to contain at least 15,000,000 tons of high-grade hematite; and there are indications of other ore deposits on the same range. The recent discoveries promise, therefore, to be of great economic importance, as well as of much interest in solving some tangled problems in connection with the oldest formation in Canada.

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11. *Final Report on the Pleistocene Beds of Canada.*

See Reports, p. 328.

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12. *Glacial Notes at Rhyd-ddu, Carnarvon.* *By* J. R. Dakyns, *M.A.*

Terminal Curvature.

Near Rhyd-ddu glacial striæ are to be seen at the following places, to wit: near the railway station, at about 627 feet above the sea, running N. 30° W.; near Rhos-clogwyn slate quarry, at 900 feet, running N. 50° W.; and near the path to Snowdon at 1,200 feet above sea level, running N. 50° W. These striæ indicate a general motion of ice down the valley of the Garfai in which Llyn Cwellyn lies.

On the west side of Llyn-y-Gader (out of which the Garfai flows), not much above the level of the lake, there is an old slate quarry in ground sloping gently to the north-east, in which the planes of slaty cleavage, striking north-east and dipping north-west, have their weathered edges bent over towards the north-west. As this coincides with the direction of ice-flow indicated by the striæ mentioned above, it is but natural to suppose that the bending over was caused by the ice moving towards the north-west.

But at quarries in the neighbourhood the cleavage planes have not been bent over; they have not been so affected at the Rhos-clogwyn quarry, near which striæ were observed, nor at the Cwm y Llan quarries; nor at two other old quarries distant only a hundred yards from that exhibiting the curvature, but on higher ground.

It is therefore clear that the moving object which bent over the cleavage planes must have been *confined to the very bottom of the valley.* The observed phenomenon could not have been caused by the glacier, whose striæ are to be seen on the rocks up to at least 1,200 feet above sea level.

Till.

In some parts of the basin of the river Colwyn a stratified stony clay exists in which the included stones are all lying flat. In one section this till is seen to consist of three perfectly distinct divisions. It seems to me to be obviously of a sedimentary origin, let down (after the manner suggested by Mr. Goodchild) as a frozen mass of mud, stones, and ice gradually melted.

WEDNESDAY, SEPTEMBER 12.

The following Papers and Reports were read:—

1. *Beach Formation in the Thirlmere Reservoir.* *By* R. D. Oldham, *Geological Survey of India.*

Readers of Mr. Marr's book on the 'Scientific Study of Scenery' will recall the contrast drawn between the irregular and angular outline of the Thirlmere Lake reservoir, due to the submergence of a land surface shaped by subaërial denudation, as contrasted with the more gracefully curved outline of the natural lakes, where wind, waves, and streams have combined to round off the angularities by wearing away the prominences and filling up the re-entering angles. This reproach seems to the author to be somewhat exaggerated, as the shore lines of the Cumberland Lakes have only been partially remodelled by wave action and delta formation, and the original outlines due to simple submergence are still to be seen. However this may be, the reproach, such as it is, is in process of removal. All along the shore of the Thirlmere Lake incipient beach erosion is to be seen, and towards the northern end of the lake, where the shores close in and are exposed to the force of the waves driven along the length of the lake by the prevailing southerly winds, typical beaches and beach curves are being developed. Lantern slides showing the as yet incompleted transition from the irregular outlines produced by submergence

to the regular curves of beach formation were exhibited and attention drawn to this interesting opportunity of witnessing the gradual formation and growth of a beach.

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2. *The Basal (Carboniferous) Conglomerate of Ullswater and its Mode of Origin. By* R. D. OLDHAM, *Geological Survey of India.*

On the western shore of Ullswater, near its lower end, a good section has recently been exposed of the basal conglomerates, variously ascribed to Old Red or lowermost Carboniferous age. This conglomerate has been considered as glacial in its origin, but does not appear to the author to present any true glacial characteristics. It contains angular and subangular blocks of all sizes, which are not scattered indiscriminately, but are arranged with a distinct, though obscure, banding. In the admixture of blocks of all sizes and the absence of rounded boulders, it differs from the known river deposits of temperate climes, and more closely resembles the accumulations of debris which result from cloud-bursts than any other form of deposit which can be observed in the British Isles at the present day. The conglomerate cannot, however, be reasonably attributed to any such local deposits; its true analogue must be looked for in the dry regions of Western and Central Asia, where all rainfall rushes off the bare hills, producing an effect very like that of a cloud-burst in our own climate, and causing a mixed mass of water, silt, and stones to rush down the river channels, which are dry or carry only a feeble stream in ordinary times. This mass of material is carried out from the hills, and forms a deposit with a gently sloping surface extending for miles into the open country. Carried along in this manner the rock fragments do not undergo the rounding which they suffer in a more permanent torrent, and are deposited, on the sudden subsidence of the flood, in a mixed mass of fragments of all sizes. The sections exposed along the roadside near the foot of Ullswater not only exhibit a rude banding, due to the action of successive floods, but also show patches of current-bedded, fine-grained, gravelly material, representing the action of the feebler stream which continued after the passage of the flood.

The conclusion drawn is that the conglomerate is a torrential deposit, formed on dry land, near the foot of a range of hills, in a generally dry climate, varied by seasonal or periodical bursts of rain. The red colour of the fine-grained material suggests tropical or sub-tropical conditions, as the formation of red soils is at the present day much more common in tropical than in temperate regions to such a degree that it may almost be regarded as characteristic of a hot climate.

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3. *Report on Photographs of Geological Interest.*— See Reports, p. 350.

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4. *Sections at the Alexandra Dock Extension, Hull. By* W. H. CROFTS.

These works situated immediately to the east of the Alexandra Dock, and covering about seven acres, necessitated the excavation of earth *in situ* to a depth of about 20 feet over a great part of this area, the trenches being eight or twelve feet deeper. The formations exhibited are glacial and post-glacial.

There is evidence of a basin in chalk corresponding with the valley of the river Hull, the top of the chalk on the east side of the valley being in places higher than in the bed of the river.

The glacial deposits reach from the sea on the east up the slope of the Wolds on the west: these beds are depressed in the neighbourhood of Hull; this depression is filled in with warp.

The Humber warp to the extent of upwards of twelve feet covered the whole area of the works; below this over a greater part of this area a peat and clay bed exists, varying from one inch to three feet in thickness, resting on glacial beds of a varied character which borings show to be about sixty feet thick, with angular chalk and flint gravel between them and the solid chalk.

The deepest part of the wall trenches was about forty feet, but the general depth was thirty to thirty-four feet below O.D.

The trench of the eastern wall showed the following section at the south end.

	Ft.	In.
Laminated Warp	12	0
Shell Bed	0	3
Silt	1	6
Shell Bed	1	0
Glacial Gravels	11	0
Compact Boulder Clay	3	0

Towards the north the surface of the Boulder Clay rises, a bed of stoneless red clay intrudes in the upper portion of the gravels, a peat bed makes its appearance, one of the shell beds disappears, and the toe of a sandy balk is introduced under the warp. At the north end of this trench there are two beds of Boulder Clay separated by gravels, the red clay having disappeared; otherwise the section is similar to that last described.

The shell bed contained Cardium edule, Tellina solidula, Scrobicularia piperata, Utriculus obtusus, Rissoa ulva, Littorina rudis, L. obtusata, Mytilus edulis, Pholas candida, and Nassa incrassata, the latter five being new records for this bed.

The large number of very young specimens and both valves being often intact indicate but a short journey and beach-like conditions.

The surface of the clay and peat bed was level and undisturbed, except that the smaller shells of the shell bed above penetrated into numerous crack-like crevices, and seemed to indicate that the clay had been exposed and sun-dried before the waters of the estuary formed their shell beach.

The shell bed underlying the warp and the method of deposition of the warp appear to suggest that, whether the clay below was deposited under conditions due to subsidence, sudden or rapid, or not, a gradual subsidence took place during the deposition of the warp.

In the clay and peat bed there were stumps of trees, including oak (Quercus pedunculata), with the roots extending several feet into the glacial beds below; a number of perfect cherries (Prunus Padus) were found, the quantity and condition of which may suggest that the trees were bearing fruit at the time of the first inundation; a few pieces of charcoal grouped together were also found in this bed, but careful search revealed nothing that could be attributed to human agency.

Note.—Upper Shell Bed and top of Clay and Peat Bed, about 13 ft. below O.D.; High Water ordinary Spring Tides, about 12 ft. above O.D.; Low Water ordinary Spring Tides, about 10 ft. below O.D.

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5. *The Jurassic Flora of East Yorkshire. By* A. C. Seward, *F.R.S.*

The plant-beds exposed in the cliff sections of the Yorkshire coast have afforded unusually rich data towards a restoration of the characteristics and composition of a certain facies of Mesozoic vegetation. Rich collections of plants from Gristhorpe Bay and other well-known localities are found in the British Museum, also in the Museums of Scarborough, Whitby, Cambridge, Oxford, Manchester, York, Newcastle, Leeds, and elsewhere. The Natural History Museum, Paris, contains several important Yorkshire plants, some of which have been described by Brongniart and Saporta. The following species have been recognised from the East Yorkshire area:—

Marchantites erectus (Leck., ex Bean, MS.); *Equisetites columnaris*, Brongn.; *Equisetites Beani* (Bunb.); *Lycopodites falcatus*, L. & H.; *Cladophlebis denticulata* (Brongn.); *C. haiburnensis* (L. & H.); *C. lobifolia* (Phill.); *Coniopteris arguta* (L. & H.); *C. hymenophylloides* (Brongn.); *C. quinqueloba* (Phill.); *Dictyophyllum rugosum*, L. & H.; *Klukia exilis* (Phill.); *Laccopteris polypodioides* (Brongn.); *L. Woodwardi* (Leck.); *Matonidium Goepperti* (Ett.); *Pachypteris lanceolata*, Brongn.; *Ruffordia Goepperti* (Dunk.); *Sagenopteris Phillipsi* (Brongn.); *Sphe-*

nopteris Murrayana (Brongn.); *S. Williamsoni*, Brongn.; *Tæniopteris major*, L. & H.; *T. vittata*, Brongn.; *Todites Williamsoni* (Brongn.); *Anomozamites Nilssoni* (Phill.); *Araucarites Phillipsi*, Carr; *Baiera gracilis*, Bunb.; *B. Lindleyana* (Schimp.); *B. Phillipsi*, Nath.; *Beania gracilis*, Carr; *Brachyphyllum mamillare*, Brongn.; *Cheirolepis setosus* (Phill.); *Cryptomerites divaricatus*, Bunb.; *Ctenis falcata*, L. & H.; *Czekanowskia Murrayana* (L. & H.); *Dioonites Nathorsti*, sp. nov.; *Ginkgo digitata* (Brongn.); *G. whitbiensis*, Nath.; *Nageiopsis anglica*, sp. nov.; *Nilssonia compta* (Phill.); *N. mediana* (Leck., ex Bean, MS.); *N. tenuinervis*, Nath.; *Otozamites acuminatus* (L. & H.); *O. Beani* (L. & H.); *O. Bunburyanus*, Zign.; *O. Feistmanteli*, Zign.; *O. graphicus* (Leck., ex Bean, MS.); *O. obtusus* (L. & H.), *var. ooliticus*; *O. parallelus* (Phill.); *Pagiophyllum Williamsoni* (Brongn.); *Podozamites lanceolatus* (L. & H.); *Ptilozamites* (Leck., ex Bean, MS.); *Taxites zamioides* (Leck.); *Williamsonia gigas* (L. & H.); *W. pecten* (Phill.).

The English flora is compared by the author with Rhætic, Jurassic, and Wealden floras of other regions; a comparison is made also between the fossil flora and the vegetation of the present day.

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6. *Note on the Age of the English Wealden Series.* *By* G. W. Lamplugh, *F.G.S., of H.M. Geological Survey.*

In recent discussions arising from the renewed attempts to define more closely the boundary between the Jurassic and Cretaceous systems in Russia, Germany, Belgium, and France, and also in North America, constant reference has been made to the English Wealden deposits as affording a standard of comparison. But meanwhile doubt has been thrown, by palæontologists who have studied certain portions of the Wealden flora and fauna, on the hitherto accepted classification of these English deposits with the Lower Cretaceous, on the ground that the fossils showed strong Jurassic affinities. This opinion has been expressed by the late Professor O. C. Marsh in regard to the reptiles, by Dr. A. Smith Woodward in regard to the fish, and by A. C. Seward in regard to the plants. To prevent further confusion it is therefore desirable that certain facts which have been overlooked in this discussion, though for the most part already published, should be restated, since these facts seem sufficient to prove that at any rate the greater portion of the English Wealden series must remain as part of the Lower Cretaceous.

It has not always been sufficiently borne in mind that the accumulation of the Wealden Series must have required a period of long duration. The sands of the Hastings Beds may indeed have been deposited rather rapidly, but the shaly clays with layers of shells and cyprids interstratified with these sands indicate slower sedimentation, and the great mass of Weald Clay, reaching 1,000 feet in thickness, must represent an epoch of great length. Hence, since it is universally acknowledged that the fresh-water conditions did not set in until the closing stages of the Jurassic period, it seems inevitable from this consideration alone that such conditions persisted into Lower Cretaceous times.

Again, nearly all the 'Wealden' fossils in which Jurassic affinities have been observed have been obtained from the lower part of the Wealden series (*i.e.* from the Hastings Beds), and very little is known respecting the corresponding fossils from the Weald Clay which probably represents the major portion of the Wealden period.

Moreover, the argument from the Jurassic affinities of the land and fresh-water fossils alone inspires no confidence, since if we eliminate the Lower Wealden fossils from the Lower Cretaceous lists our knowledge is practically limited to the marine life of this period; and it may be legitimately asked whether the land and fresh-water fossils of the Hastings Beds are not, after all, of the character proper to the lowermost part of the Cretaceous, wherein a close relationship to the immediately preceding period seems quite appropriate.

It is from the stratigraphical evidence, however, that the Lower Cretaceous

age of at least the greater portion of the English Wealden Series can be most satisfactorily established, by its relation to the marine sequence which must form the ultimate basis of the classification. The marine beds directly overlying the Weald Clay in the south of England represent only the latest stage (Aptien) of the Lower Cretaceous period; and although there is a sharp line of demarcation at their base, this seems to denote a rapid change of conditions and not a lengthy time-interval, since the incoming of marine or brackish-water shells near the top of the Wealden strata in Dorset, Hampshire, and Surrey, foreshadowing the termination of the fresh-water episode, indicates that the series is practically complete, and has undergone little if any erosion in these parts before the deposition of the overlying marine strata. Such erosion may, however, have taken place locally towards the easterly and westerly terminations of the basin of deposition, where the topmost beds of the Wealden Series are not found.

In the Speeton Clay, where the Lower Cretaceous marine sequence is fully represented, the equivalents of the Lower Greensand and Atherfield Clay of the south of England are comprised within a relatively narrow compass in the sparingly fossiliferous upper part of the sequence;[1] and therefore by far the greater portion of the Lower Cretaceous period, if represented at all in the south of England, must be represented in the Wealden Series. The portion of the Speeton Clay unrepresented by marine sediments in the south includes the lower part of the Zone of *Belemnites brunsvicensis*, and the whole of the Zone of *Bel. jaculum*, both undoubtedly Lower Cretaceous (*Barrémien*, *Hauterivien*, and *Valanginien*), together with the whole of the Zone of *Bel. lateralis*, the fauna of which shows Jurassic affinities. Furthermore, in tracing this marine series southward from Yorkshire through Lincolnshire into Norfolk, the author has found that in the latter county the lower zones are apparently absent, and the remaining portion, representing probably the lower part of the Zone of *Bel. brunsvicensis*, is characterised by the presence among the marine fossils of plant remains, chiefly fragments of a Wealden fern, *Weichselia* (*Mantelli?*), and by other indications of fluviatile influence, suggesting the beginning of a lateral change into Wealden conditions.[2]

With the well-recognised gradual development of fresh-water conditions in the Purbeck beds of the Wealden area towards the close of the Jurassic period, and indications of the reversal of this process in the top of the Weald Clay during the later stages of the Lower Cretaceous, and with evidence for a lateral passage of part of the Lower Cretaceous marine sediments of the North of England into estuarine deposits further south, there seems every reason to believe that in the fresh-water or estuarine strata of the English Wealden the whole of the time-interval between the Portlandian and Aptien stages is represented, and that it would be equally erroneous to classify the series entirely with the Jurassic system and entirely with the Cretaceous, if the hitherto recognised boundary of these systems in the marine deposits of other areas is to be maintained.

The deposits classed as Wealden in Belgium, Germany, and France appear to be much more restricted in vertical range than the English series, and to represent different parts of the period in different places, but nowhere to imply the same long continuance of fresh-water conditions in a single area.

[1] See *Summary of Progress of the Geological Survey for* 1897, p. 129.
[2] See Survey Mem. *Borders of the Wash* (sheet 69 O.S)., pp. 21–25.

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7. *Report on the Irish Elk Remains in the Isle of Man.*
See Reports, p. 349.

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION—RAMSAY H. TRAQUAIR, M.D., LL.D., F.R.S.

THURSDAY, SEPTEMBER 6.

The President delivered the following Address:—

IN opening to-day the sittings of the Zoological Section, I must first express my sense of the honour which has been conferred on me in having been chosen as your President on this occasion, and I may add that I feel it not only as an honour to myself personally but also as a compliment to the field of investigation in which the greater part of my own original work has been done. It is a welcome recognition of the doctrine, which I, and much more important men indeed than I, have always maintained, namely, that Palæontology, however valuable, nay, indispensable, its bearings on Geology may be, is in its own essence a part of Biology, and that its facts and its teachings must not be overlooked by those who would pursue the study of Organic Morphology on a truly comprehensive and scientific basis. As I have asked on a previous occasion, 'Does an animal cease to be an animal because it is preserved in stone instead of spirits? Is a skeleton any the less a skeleton because it has been excavated from the rock, instead of prepared in a macerating trough?' And I may now add—Do animals, because they have been extinct for it may be millions of years, thereby give up their place in the great chain of organic being, or do they cease to be of any importance to the evolutionist because their soft tissues, now no longer existing, cannot be imbedded in paraffine and cut with a Cambridge microtome?

These are theses which I think no one denies theoretically; but what of the practical application of the rule? For though cordially thanking my biological brethren for the honour they have done me in placing me in this chair to-day, I must ask them not to be offended if I say that in times past I have a few things against some of them at least. I refer first to the apathy concerning palæontological work, more especially where fishes are concerned, which one frequently meets with in the writings of biologists, as seen in the setting up of classifications and theories and the erection of genealogical trees without any, or with at least inadequate, enquiry as to whether such theories or trees are corroborated by the record of the rocks. But more vexatious still are the offhand proceedings of some biologists who, when they wish to complete their generalisations on the structure of a living organism, or group of organisms, by allusion to those which in geological time have gone before, do not take the trouble to consult the original palæontological memoirs or papers, or to make themselves in any way practically acquainted with the subject, but derive their knowledge at second or third hand from some text-book or similar work, which may not in every case be exactly up to date on the matters in question. Nay, more than this, I think I have seen the authors of such text-books or treatises credited with facts and illustrations which were due to the labours of hard-working palæontologists years before.

But a better time, I am convinced, is not far off, when the unity of all biological science will be recognised not merely theoretically but also practically by workers in every one of its branches.

Of one thing I must however warn those who have hitherto devoted their time exclusively to the investigation of things recent, namely, that a special training is necessary for the correct interpretation of fossil remains, especially those of the lower Vertebrata and many groups of Invertebrata. So it comes that what looks to the uninitiated eye a mere confused mass of broken bones or plates may to the trained observer afford a flood of valuable light on questions of structure previously undetermined. We must take into account the condition of the fossil as regards mineralisation and crushing; we must learn to recognise how the various bones may be dislocated, scattered, or shoved over each other, and to distinguish true sutures from mere fractures. We must carefully correlate the positive results obtained from one specimen with those afforded by others, and in this way it happens that to make a successful restoration of the exo- or endo-skeleton of a fossil fish or reptile may require years of patient research. But the thought sometimes does come up in my mind, that some people imagine that fossils, such as fishes, occur in the rocks all restored and ready, so that the author of such a restoration has no more scientific credit in his work than if he were an ordinary draughtsman drawing a perch or a trout for an illustrated book! But the student of fossil remains must learn not only to see what does exist in the specimen he examines, but also to refrain from seeing things which are not there—to know what he does not see as well as what he does see. For many grave errors have arisen from want of this necessary training, as for instance where the under surface of a fish's head has been described as the upper, or where markings of a purely petrological character have been supposed to indicate actual structures of the greatest morphological importance. Or we may find the most wonderful details described, which *may* indeed have existed, but for which the actual evidence is only the fertile imagination of the writer.

From this it will be apparent that though Palæontology is Biology and Biology includes Palæontology, yet as regards original research a division of labour is in most cases necessary. For though palæontological investigations are absolutely impossible without an adequate knowledge of recent zoology, yet the nature of the remains with which the palæontologist has to deal renders their interpretation a task of so different a character from that allotted to the investigation of the structure and development of recent forms that he will scarcely have time for the successful carrying out of a second line of research. Conversely, the same holds regarding the sphere of work of the recent biologist.

Now those last remarks of mine may perhaps tend to confirm an idea which I have at least been told is prevalent in the minds of recent biologists, namely, that the results of Palæontology are so uncertain, so doubtful, and so imperfect, that they are scarcely worthy of serious attention being paid to them. And the best answer I can make to such an opinion, if it really does exist, is to try to place before you some evidence that Palæontology is not mere fossil shell hunting, or the making up of long lists of names to help the geologists to settle their stratigraphical horizons, but may present us with abundance of matter of genuine biological interest.

Since the days of Darwin, there is one subject which more than all others engrosses the attention of scientific biologists. I mean the question of Evolution, or the Doctrine of Descent. Time was when controversies raged round the very idea of Evolution, and when men of science were divided among themselves as to whether the doctrine to which Darwin's theory of Natural Selection gave so mighty an impetus was or was not to be accepted. Times have however changed, and I hardly think that we should now find a single true scientific worker who continues to hold on by the old special creation idea. Philosophic zoologists now busy themselves either with amassing morphological evidences of Descent or with the discussion of various theories as to the factors by which organic evolution has been brought about—whether Natural Selection has been the all-sufficient cause or not, whether acquired peculiarities are transmissible, and so on.

From the nature of things it is clear that the voice of the palæontologist can only be heard on the morphological aspect of the question, but to many of us, including myself, the morphological argument is so convincing that we believe that even if the Darwinian theory were proved to-morrow to be utterly baseless, the Doctrine of Descent would not be in the slightest degree affected, but would continue to have as firm a hold on our minds as before.

Now as Palæontology takes us back, far back, into the life of the past, it might be reasonably expected that it would throw great light on the descent of animals, but the amount of its evidence is necessarily much diminished by two unfortunate circumstances. First, the terrible imperfection of the geological record, a fact so obvious to any one having any acquaintance with Geology that it need not be discussed here; and secondly, the circumstance that save in very exceptional cases only the hard parts of animals are preserved, and those too often in an extremely fragmentary and disjointed condition. But though we cannot expect that the palæontological record will ever be anything more than fragmentary, yet the constant occurrence of new and important discoveries leads us to entertain the hope that, in course of time, more and more of its pages will become disclosed to us.

Incomplete, however, as our knowledge of Evolution as derived from Palæontology must be, that is no reason why we should not appraise it at its proper value, and now and again stop for a moment to take stock of the material which has accumulated.

You are all already acquainted with the telling evidence in favour of Evolution furnished by the well-known series of Mammalian limbs, as well as of teeth, in which the progress, in the course of time, from the more general to the more special is so obvious that I cannot conceive of any unprejudiced person shutting his eyes to the inference that Descent with modification is the reason of these things being so. Suppose, then, that on this occasion we take up the palæontological evidence of Descent in the case of fishes. This I do the more readily because what original work I have been able to do has lain principally in the direction of fossil ichthyology; and again, because it does seem to me that it is in this department that one has most reason to complain of want of interest on the part of recent biologists, even, I may say, of some professed palæontologists themselves.

But the subject is really of so great an extent that to exhaust it in the course of an address like the present would be simply impossible, so I shall in the main limit myself to the consideration of Palæozoic forms, and this more especially seeing that we may hope for a large addition to our light on the fishes of the more recent geological formations from the fourth volume of the 'Catalogue of Fossil Fishes' in the British Museum, which will soon appear from the pen of my friend Dr. A. Smith Woodward. I need scarcely say how much his previous volume has conduced to a better knowledge of the Mesozoic forms.

Here I may begin by boldly affirming that I include the Marsipobranchii as fishes, in spite of the dictum of Cope that no animal can be a fish which does not possess a lower jaw and a shoulder-girdle. Why not? The position seems to me to be a merely arbitrary one; and it is, to say the least, not impossible that the modern Lampreys and Hags may be, as many believe, the degenerate descendants of originally gnathostomatous forms.

To the origin of the Vertebrata Palæontology gives us no clue, as the forerunners of the fishes must have been creatures which, like the lowest Chordata of the present day (Urochorda, Hemichorda, Cephalochorda), had no hard parts capable of preservation. And though I shall presently refer again to the subject, I may here affirm that, so far as I can read the record at least, it is impossible to derive from Palæontology any support to the view, recently revived, that the ancient fishes are in any way related to Crustacean or Merostomatous ancestors.

What have we then to say concerning the most ancient fishes with which we are acquainted?

The idea that the minute bodies, known as Conodonts, which occur from the Cambrian to the Carboniferous, are the teeth of fishes and possibly even of ancient

Marsipobranchs may now be said to be given up. They are now accepted by the most reliable authorities as appertaining to Invertebrata such as Annelides and Gephyrea.

More recently, however, Rohon[1] has described from the Lower Silurian of the neighbourhood of St. Petersburg small teeth (*Palæodus* and *Archodus*) associated with Conodonts, and which seem to be real fish teeth, but not of Selachians, as is shown by the presence of a pulp cavity surrounded by non-vascular dentine. It is impossible to say anything more of their affinities.

Obscure and fragmentary fish remains have been obtained by Walcot, and described by Jaekel, from rocks in Colorado supposed to be of Lower Silurian or Ordovician age.[2] But doubts have been thrown on their age, and the fossils themselves, which have, it must be owned, a very Devonian look about them, are so extremely fragmentary that they do not help us much in our present purpose.

It is not till we come to the Upper Silurian rocks that we begin to feel the ground securely under our feet, though we may be certain, from the degree of specialisation of the forms which we there find, that fishes lived in the waters of the globe for long ages previously.

Characteristic of the 'Ludlow bone-bed' are certain minute scales on which Pander founded the family Cœlolepidæ, having a flat or sculptured crown, below which is a constricted 'neck,' and then a base usually perforated by an aperture leading into a central pulp cavity. As these little bodies, looked upon by Agassiz as teeth, were shown by McCoy to be scales, and as they occurred at Ludlow in England and Oesel in Russia along with small Selachian spines (*Onchus*), they were usually considered as appertaining, with the latter, to small Cestraciont sharks. The genera *Thelodus*, *Cœlolepis*, and others were founded on these dermal bodies, but it is doubtful if any but the first of these names will stand.

But the aspect of affairs was altogether changed by the discovery three years ago by the officers of the Geological Survey of entire specimens of *Thelodus* in the Upper Silurian rocks of the South of Scotland, from which it was evident that the fish, though somewhat shark-like, could hardly be reckoned as a true Selachian.[3] *Thelodus scoticus*, Traq., has a broad flattened anterior part corresponding to the head and forepart of the body, very bluntly rounded in front, and passing behind into right and left angular flap-like projections, which are sharply marked off from the narrow tail, which is furnished with a deeply cleft heterocercal caudal fin. Unless the flap-like lateral projections are representatives of pectorals, no other fins are present, neither do we find any teeth or jaws, nor any trace of internal skeleton; and it is only a few days since Mr. Tait, collector to the Geological Survey of Scotland, pointed out to me in a recently acquired specimen a right and left dark spot at the outer margins of the head near the front, which spots may indicate the position of the eyes.[4] A previously unknown genus, *Lanarkia*, Traq., also occurred, in which the creature had the very same form, but instead of having the skin clothed with small shagreen-like scales, possessed, in their place, minute sharp conical hollow spines, without base and open below. What we are to think of those two ancient forms, apparently so primitive, and yet undoubtedly also to a great extent specialised, we shall presently discuss.

Let us now for a moment look at the genus *Drepanaspis*, Schlüter, from the Lower Devonian of Gmünden in Western Germany.[5] We have here a strange

[1] 'Ueber untersilurische Fische,' *Mélanges Géol. et Paléont.* vol. i. (St. Petersburg, 1889), pp. 9–14.

[2] *Bulletin Geol. Soc. America*, vol. iii. 1892, pp. 153–171.

[3] R. H. Traquair, 'Report on Fossil Fishes collected by the Geological Survey in the Silurian Rocks of the South of Scotland,' *Trans. Roy. Soc. Edin.*, vol. xxxix. 1899, pp. 827–864. A specimen of *Thelodus* had, however, been found by Mr. James Young, of Lesmahagow, before the Geological Survey came on the scene.

[4] I am indebted to Sir A. Geikie, F.R.S., Director-General of the Geological Survey, for permission to make use of this and other facts disclosed by Mr. Tait's work in the Lesmahagow Silurians during the present summer.

[5] R. H. Traquair, *Geol. Mag.*, April 1900.

creature whose shape entirely reminds us of that of *Thelodus*, having the same flat broad anterior part, bluntly rounded in front, and angulated behind, to which is appended a narrow tail ending in a heterocercal caudal fin, which is, however, scarcely bilobate. But here the dermal covering, instead of consisting of separate scales or spinelets, shows a close carapace of hard bony plates, of which two are especially large and prominent—the median dorsal and the median ventral—other large ones being placed around the margins, while the intervening space is occupied by a mosaic of small polygonal pieces. The position of the mouth, a transverse slit, is seen just at the anterior margin; it is bounded behind by a median mental or chin-plate, but no jaws properly so called are visible, nor are there any teeth. Then on each margin near the front of the head is a small round pit, exactly in the position of the dark spot seen in some examples of *Thelodus*, which, if not an orbit, must indicate the position of some organ of sense. Again, the tail is covered with scales after the manner of a 'ganoid' fish, being rhombic on the sides, but assuming the form of long deeply imbricating fulcra on the dorsal and ventral margins. The position of the branchial opening, or openings, has not yet been definitely ascertained.

All these plates are closely covered with stellate tubercles, and we cannot escape from the conclusion that they are formed by the fusion of small shagreen bodies like those of *Thelodus*, and united to bony matter developed in a deeper layer of the skin.

If the angular lateral flaps of *Thelodus* represent pectoral fins, then we should have the exceedingly strange phenomenon of such structures becoming functionally useless by enclosure in hard unyielding plates, though still influencing the general outline of the fish. Be that as it may, can we doubt that in *Drepanaspis* we have a form derived by specialisation from a Cœlolepid ancestor?

This *Drepanaspis* throws likewise a much-desired light on the fragmentary Devonian remains known since Agassiz's time as *Psammosteus*. These consist of large plates and fragments of plates, composed of vaso-dentine, and sculptured externally by minute closely set stellate tubercles, exactly resembling the scales of some species of *Thelodus*. These tubercles are also frequently arranged in small polygonal areas, reminding us exactly of the small polygonal plates of *Drepanaspis*, and, like them, often having a specially large tubercle in the centre. That *Psammosteus* had an ancestry similar to that of *Drepanaspis* can also hardly be doubted.

Finally, in the well-known *Pteraspis* of the Upper Silurian and Lower Devonian formations we have a creature which also has the head and anterior part of the body enveloped in a carapace, to which a tail covered with rhombic scales is appended behind, and, though the caudal fin has never been properly seen, such remains of it as have occurred distinctly indicate that it was heterocercal in its contour. The plates of the carapace have a striking resemblance in general arrangement to those of *Drepanaspis*, though the small polygonal pieces have disappeared, and there is a prominent pointed rostrum in front of the mouth; and it is to be noted that the small round apertures usually supposed to be orbits are in a position quite analogous to that of the sensory pits in *Drepanaspis*. The plates of the carapace of *Pteraspis* are not, however, tuberculated, but ornamented by fine close parallel ridges, the microscopic structure of which, along with their frequent lateral crenulation, leaves no doubt in our minds that they have been formed by the running together in lines of *Thelodus*-like shagreen grains. An aperture supposed to be branchial is seen on the plate forming the posterior angle of the carapace on each side.

Until these recent discoveries concerning the Cœlolepidæ and Drepanaspidæ, *Pteraspis* and its allies, *Cyathaspis* and *Palæaspis*, constituted the only family included in the order Heterostraci of the sub-class Ostracodermi, distinguished, as shown by Lankester, by the absence of bone lacunæ in the microscopic structure of their plates. It is now, however, clear that we can trace them back to an ancestral family in which the external dermal armature was still in the generalised form of separate shagreen grains or spinelets.

But the Ostracodermi are usually made to include two other groups or orders, namely the Osteostraci and the Asterolepida.[1]

The Osteostraci are distinguished from the Heterostraci by the possession of lacunæ in their bone structure, and by having the eyes in the middle of the head-shield instead of at the sides. *Cephalaspis*, which occurs from the Upper Silurian to the top of the Devonian, is the best known representative of this division. Instead of a carapace, we find a large head-shield of one piece, though its structure shows evidence of its having been originally composed of a mosaic of small polygonal plates, and it is also to be noted that the surface is ornamented by small tubercles, there frequently being one larger in size in the centre of each polygonal area. The posterior-external angles of the shield project backwards in a right and left pointed process or *cornu*, scarcely developed in *C. Murchisoni*, internal to which, and also organically connected with the head-shield, is a rounded flap-like structure, which strongly reminds us of the lateral flaps of the Cœlolepidæ. The body is covered with scales, which on the sides are high and narrow; there is a small dorsal fin, and the caudal, though heterocercal, is not bilobate. It is scarcely necessary for me to add that we find just as little evidence of jaws or of teeth as in the case of the Heterostraci.

The association of the Heterostraci and Osteostraci in one sub-class of Ostracodermi has been strongly protested against by Professor Lankester and Dr. O. M. Reis, but here the Scottish Silurian strata come to the rescue with a form which I described last year under the name of *Ateleaspis tessellata*, and of which some more perfect examples than those at my disposal at that time have recently come to light through the labours of Mr. Tait, of the Geological Survey of Scotland.

Here we have a creature whose general form reminds us strongly of *Thelodus*, but whose close affinity to *Cephalaspis* is absolutely plain, were it only on account of the indications of orbits on the top of the head.

The expanded anterior part which here represents the head-shield of *Cephalaspis* shows not the slightest trace of cornua, but forms posteriorly a gently rounded lobe on each side, clearly suggesting that the cornual flaps of *Cephalaspis* are homologous with and derivable from the lateral expanses in the Cœlolepidæ. This cephalic covering is composed of numerous small polygonal plates like those of which the head-shield in *Cephalaspis* no doubt originally consisted, and the minute tubercles which cover their outer surfaces also suggest that the superficial layer was formed by the fusion of Cœlolepid scales. The body is covered with rhombic scales, sculptured externally with tubercles and wavy transverse ridges, and arranged in lines having the same general direction as the scutes of *Cephalaspis*, from which we may infer that the latter originated from the fusion of scales of similar form. The fins are as in *Cephalaspis*, there being one small dorsal situated far back, and a heterocercal caudal, which is triangular in shape, and not deeply cleft into upper and lower lobes as in the Cœlolepidæ. Finally, the scales, on microscopic examination, show well-developed bone lacunæ in their internal structure.

That *Ateleaspis* belongs to the Osteostraci there is thus not the smallest doubt, but its general resemblance to the Cœlolepidæ in its contour anteriorly led me to regard it as an annectent form, and consequently to believe that there is after all a genuine genetic connection between the Heterostraci and the Osteostraci. And I have not seen reason to depart from that opinion even though *Ateleaspis* turns out to be still closer to *Cephalaspis* than was apparent in the original specimens.

If this be so, then *Cephalaspis*, as well as *Pteraspis* and its allies, is traceable to the Cœlolepidæ, shark-like creatures in which, as we have already seen, the dermal covering consists of small shagreen-like scales, or of minute hollow spines, and consequently all theories as to the arthropod origin of the Ostracodermi, so far as they are founded on the external configuration of the carapace in the more

[1] To these I myself recently added a fourth, the Anaspida, for the remarkable Upper Silurian family of Birkeniidæ, but as these throw no light as yet on the problem of Descent they may at present be only mentioned.

specialised forms, must fall to the ground. And from the close resemblance of these scales of *Thelodus* to Elasmobranch shagreen bodies—for forty-five years they had been, by most authors, actually referred to the Selachii—I concluded that the Cœlolepidæ owed their origin to some form of primitive Elasmobranchs. That is, however, not in accordance with the view of the late Professor Cope, that the Ostracodermi are more related to the Marsipobranchii, and that, from the apparent absence of lower jaw, they should be placed along with the last-named group in a class of Agnatha, altogether apart from the fishes proper. And Dr. Smith Woodward, who is inclined to favour Cope's theory, has expressed his view that the similarity of the Cœlolepid scales to Elasmobranch shagreen is no proof of an Elasmobranch derivation, but that such structures, representing the simplest form of dermal hard parts, may have originated independently in far distant groups.[1] Knowing what we do of the occurrence of strange parallelisms in evolution, it would not be safe to deny such a possibility. But as to a Marsipobranch affinity, I would point out that the apparent want of lower jaw among the hard parts which nature has preserved for us is no proof of the absence of a Meckelian cartilage among the soft parts which are lost to us for ever; and also, as Professor Lankester has remarked, that there is no evidence whatever that any of the creatures classed together as Ostracodermi were monorhinal like the Lampreys. The only fossil vertebrate having a single median opening, presumably nasal, in the front of the head is *Palæospondylus*, but, whatever be the true affinities of this little creature, at present the subject of so much dispute, I think we may be very sure that it is not an Ostracoderm.

The Devonian 'Antiarcha' or Asterolepida, of which *Pterichthys* is the best known genus, are also usually placed in the Ostracodermi, with which they agree in the possession of a carapace of bony plates, in the absence of distinct lower jaw or teeth, in the non-preservation of internal skeleton, and in having a scaly tail furnished with a heterocercal caudal fin, and, as in the Cephalaspidæ, also with a small dorsal. But they have in addition a pair of singular jointed thoracic limbs, evidently organs of progression, which are totally unlike anything in the Osteostraci or in the Heterostraci, or indeed in any other group of fishes. These limbs are covered with bony plates and hollow inside; but though I once fancifully compared them in that respect with the limbs of insects, I must protest strongly against this expression of mine being quoted in favour of the arthropod theory of the derivation of the Vertebrata!

Nor do I think that there is any probability in the view published by Simroth nine years ago,[2] namely, that *Pterichthys* may have been a land animal which used its limbs for progression on dry ground, and that the origin of the heterocercal tail was the bending up of the extremity of the vertebral axis caused by its being dragged behind the creature in the act of walking. That view was promulgated before the discovery of the membranous expanse of the caudal fin in this genus.

But though the Asterolepida are apparently related to and inclusible in the Ostracodermi, the geological record is silent as to their immediate origin, no intermediate forms having been found connecting them more closely with either the Heterostraci or the Osteostraci. In the possession of bone lacunæ and of a dorsal fin they have a greater resemblance to the latter, but it may be looked upon as certain that they could have had no direct origin from that group.

As regards the Ostracodermi as a sub-class, they become extinct at the end of the Devonian epoch, and cannot be credited with any share in the evolution of the fishes of more recent periods, not even if we restore the Coccosteans or Arthrodira to their fellowship. To the latter most enigmatical group, which I shall still continue to look upon as fishes, I shall make some reference further on.

Coming now to say a word regarding the Elasmobranchii, it is plain from the fin-spines found in Upper Silurian rocks that they are of very ancient origin, and that if we only knew them properly they would have a wonderful tale of evolution

[1] *Geol. Mag.*, March 1900.
[2] 'Die Entstehung der Landthiere,' Leipzig, 1891.

to tell. But their internal skeleton is from its nature not calculated for preservation, and for the most part we only know those creatures from scattered teeth, fin-spines, and shagreen, specimens showing either external configuration or internal structure being rare, especially in Palæozoic strata. But from what we do know, there is no doubt that the ancient sharks were less specialised than those of the present day, and that the recent Notidanids still preserve peculiarities which were common in the Selachii of past ages.

If we ask whether the fossil sharks throw any light on the disputed origin of the paired limbs, whether from the specialisation of right and left lateral folds, or whether that type of limb called 'archipterygium' by Gegenbaur, consisting of a central jointed axis with pre- and post-axial radial cartilage attached, was the original form, I fear we get no very definite answer from Elasmobranch palæontology. The paired fins of the Upper Devonian shark, *Cladoselache*, as described by Bashford Dean, Smith Woodward, and others, seem to favour the lateral fold theory, and Cope pointed to the right and left series of small intermediate spines which in some Lower Devonian Acanthodei (*Parexus* and *Climatius*) extend between the pectorals and ventrals as evidence of a former continuous lateral fin. So also, if I am right in looking on the lateral flaps of the Cœlolepidæ as fins, the evidence of these ancient Ostracodermi would be in the same direction.

But, on the other hand, we have the remarkable group of Pleuracanthidæ, extending from the Lower Permian back to the Upper Devonian, in which the paired fins are represented by an 'archipterygium' which in the pectoral at least is biserial.

From this biserial 'archipterygium' in the Pleuracanthidæ, Professor A. Fritsch, ten years ago,[1] derived the tribasal arrangement of modern sharks, much according to the Gegenbaurian method, effecting, however, a compromise with the lateral fold theory by assuming that the Pleuracanth form originated from one, consisting of simple parallel rods, like that described in *Cladoselache*.

In my description of the pectoral fin of the Carboniferous *Cladodus Neilsoni*[2] I have shown that the cartilaginous structures apparently present a uniserial archipterygium intermediate between the arrangement in *Pleuracanthus* and that in the modern sharks, but I felt compelled to acknowledge that the specimen might also be interpreted in exactly the opposite way, namely, as an example of a transition from the 'ptychopterygium' of *Cladoselache* to the Pleuracanth and Dipnoan limb. And so in fact this fin of *Cladodus* is claimed in support of their views by both parties in the dispute.

When we add that Semon emphatically denies that there is any proof for considering that the pectoral fin of *Cladoselache* is primitive in its type,[3] and that Campbell Brown, in his recent paper on the Mesozoic genus *Hybodus*,[4] supports Gegenbaur's theory, it will be seen that Elasmobranch palæontology has not as yet uttered any very clear or decided voice on the question as to whether the so-called archipterygium is the primary form of paired fin in the fish, or only a secondary modification. We shall now inquire if we can obtain any more light on the subject from the Crossopterygii and Dipnoi.

The Crossopterygii are a group of Teleostomous fishes, characterised externally by their jugular plates and lobate paired fins, and represented in the present day only by the African genera *Polypterus* and *Calamoichthys*, which together form the peculiar family Polypteridæ. The Crossopterygii appear suddenly in the middle of the Devonian period, their previous ancestry being unknown to us.

Four families[5] are known to us in Palæozoic times—the Osteolepidæ, Rhizo-

[1] 'Fauna der Gaskohle und der Kalksteine der Permformation Böhmens,' vol. iii. pt. i. (Prague, 1890), pp. 44–45.

[2] *Trans. Geol. Soc.* (Glasgow), vol. xi. pt. i., 1897, pp. 41–50.

[3] 'Die Entwickelung der paarigen Flossen des Ceratodus Forsteri.' Jena, 1898.

[4] 'Ueber das Genus *Hybodus* und seine systematische Stellung,' *Palæontographica*, vol. xlvi. 1900.

[5] *Five*, if we include the singular and still imperfectly known Tarrasiidæ of the Lower Carboniferous.

dontidæ, Holoptychiidæ, and Cœlacanthidæ, but it is only with the first three that we have at present to deal. The Osteolepidæ and Rhizodontidæ, which appear together in Middle, and die out together in Upper Palæozoic times, resemble each other very closely. In both we have the paired fins, more especially the pectoral, obtusely or subacutely lobate: there are two separate dorsal fins, one anal, and the other caudal, which is usually heterocercal, though in some genera it is more or less diphycercal. In both the teeth are conical and have the same complex structure, the dentine being towards the base thrown into vertical labyrinthic folds, exactly as in the Stegocephalian Labyrinthodonts, and this along with the lung-like development of the double air-bladder in the recent Polypteridæ has given rise to the view that from these forms the Stegocephalia have originated. The nasal openings must have been on the under surface of the snout, as in the Dipnoi.

Of these two so closely allied families we must conclude that the Osteolepidæ are the more primitive, as in them the scales are acutely rhombic and usually covered with a thick layer of ganoine, while in the Rhizodontidæ they are rounded, deeply imbricating, and normally devoid of the ganoine layer, which, however, occasionally recurs on the scales of *Rhizodopsis* and the fin-rays of *Gyroptychius*.

What then of the structure of the paired fins? Fortunately in the Rhizodont genera *Tristichopterus* and *Eusthenopteron* the internal skeleton of the lobe was ossified, and what we see clearly exhibited in the pectoral of some specimens is striking enough. We have a basal piece attached to the shoulder-girdle and followed by a median axis of four ossicles placed end to end. The first of these shows on its postaxial margin a strong projecting process, while to its preaxial side, close to its distal extremity, a small radial piece is obliquely articulated, and a similar one is joined also to the second and third segments of the axis. The arrangement in the ventral fin is essentially similar.

In fact we have in the Rhizodontidæ a short uniserial 'archipterygium,' and the question is, Has this been formed by the shortening up and degeneration of an originally elongated and biserial one, or on the other hand do we find here a condition in which the stage last referred to has not yet been attained? This question is inseparable from the next, whether the Rhizodonts or the Holoptychians form the most advanced type.

The Holoptychiidæ resemble the Rhizodontidæ extremely closely in their external head-bones, in their rounded, deeply imbricating scales, and in the form and arrangement of their median fins. But the teeth show a more complex and specialised structure than those of the Rhizodontidæ; the simple vertical vascular tubes formed by the repeated folding of the dentine in that family being connected by lateral branches around which the dentine tubules are grouped in such a way as to give rise in transverse sections to a radiating arborescent appearance; hence the term 'dendrodont.' In this respect, then, the Holoptychiidæ show an advance on the Rhizodontidæ—what then of the paired fins? While the ventral remains subacutely lobate, as in the previous family, the pectoral has now assumed an elongated *acutely lobate* shape, with the fin-rays arranged along the two sides of a central scaly axis exactly as in the Dipnoi; and though the internal skeleton has not yet been seen, yet, judging by analogy, we cannot escape the belief that it was in the form of a complete biserial 'archipterygium.'

What, then, is the condition of affairs in the oldest known Dipnoan?

The oldest member of this group with whose configuration we are acquainted is *Dipterus*, which likewise appears in the middle of the Devonian period simultaneously with the Osteolepidæ, Rhizodontidæ, and Holoptychiidæ. In external form it closely resembles a Holoptychian, having a heterocercal caudal fin, two similarly placed dorsals, one anal, and circular imbricating scales, which, however, have the exposed part covered with smooth ganoine. But now we have the ventrals as well as the pectorals acutely lobate in shape, and presumably archipterygial in structure; the top of the head is covered with many small plates, there is no longer a dentigerous maxilla, the skull is autostylic, and the palatopterygoids and the mandibular splenial are like those of *Ceratodus* and bear each a tooth-plate with radiating ridges.

Now, comparing *Dipterus* with the recent *Ceratodus* and *Protopterus*, the first

conclusion we are likely to draw is, that the older Dipnoan is a very specialised form, that its hèterocercal tail and separate dorsals and anal are due to specialisation from the continuous diphycercal dorso-ano-caudal arrangement in the recent forms, that the Holoptychiidæ were developed from it by shortening up of the ventral archipterygium, as well as by the changes in cranial structure, and that the Rhizodontidæ and Osteolepidæ are a still more specialised series in which the pectoral archipterygium has also shared the fate of the ventral in becoming shortened up and uniserial.

Five years ago, however, M. Dollo, of the Natural History Museum at Brussels, the well-known describer of the fossil reptiles of Bernissart, proposed a new view to the effect that the process of evolution had gone exactly in the opposite direction; [1] and after long consideration of the subject I find it difficult to escape from the conclusion that this view is more in accordance with the facts of the case, though, as we shall see, it also has its own difficulties.

I have already indicated above that we are, on account of the more specialised structure of the teeth, justified in considering the Holoptychians, with their acutely lobate pectorals, a newer type than the Rhizodonts, even though they did not survive so long in geological time. What, then, of the question of autostyly?

We do not know the suspensorium of *Holoptychius*, but that of the Rhizodontidæ was certainly hyostylic, as in the recent *Polypterus*. Now as there can be no doubt that the autostylic condition of skull is a specialisation on the hyostylic form, as seen also in the Chimæroids and in the Amphibia, to suppose that the hyostylic Crossopterygii were evolved from the autostylic Dipnoi is, to say the least, highly improbable; in my own opinion, as well as in that of M. Dollo, it will not stand. And if we assume a genetic connection between the two groups it is in accordance with all analogy to look on the Dipnoi as the children and not as the parents of the Crossopterygii.

M. Dollo adopts the opinion of Messrs. Balfour and Parker that the apparently primitive diphycercal form of tail of the recent Dipnoi is secondary, and caused by the abortion of the termination of the vertebral axis as in various 'Teleostei,' so that no argument can be based on the supposition that it represents the original 'protocercal' or preheterocercal stage. Very likely that is so, but it is not of so much importance for the present inquiry, as both in the Osteolepidæ and Rhizodontidæ we find among otherwise closely allied genera some which are heterocercal, others more or less diphycercal. *Diplopterus*, for example, differs from *Thursius* only by its diphycercal tail, and in like manner among the Rhizodontidæ *Tristichopterus* is heterocercal, *Eusthenopteron* is nearly diphycercal, and there can be no doubt that, in spite of this, their caudal fins are perfectly homologous structures.

But of special interest is the question of the primitive or non-primitive nature of the continuity of the median fins in the recent Dipnoi. Like others I was inclined to believe it primitive, and that the broken-up condition of these fins in *Dipterus* was a subsequent specialisation, and in fact gave the series *Phaneropleuron*, *Scaumenacia*, *Dipterus macropterus*, and *D. Valenciennesii* as illustrating this process of differentiation.[2] This view of course draws on the imperfection of the geological record in assuming the existence of ancient pre-Dipterian Dipnoi with continuous median fins, which have never yet been discovered. But Dollo, using the very same series of forms, showed good reason for reading it in exactly the opposite direction.

The series is as follows:—

1. *Dipterus Valenciennesii* Sedgw. and Murch., from the Orcadian Old Red, and the oldest Dipnoan with whose shape we are acquainted, has two dorsal fins with *short* bases, a heterocercal caudal, and one short-based anal.

2. *Dipterus macropterus* Traq., from a somewhat higher horizon in the Orcadian series, has the base of the second dorsal much *extended*, the other fins remaining as before.

[1] 'Sur la Phylogénie des Dipneustes,' *Bulletin Soc. belge géol. paléont. hydr.*, vol. ix. 1895.

[2] *Geol. Mag.* (3), vol. x. 1893, p. 263.

3. In *Scaumenacia curta* (Whiteaves), from the Upper Devonian of Canada, the first dorsal has advanced considerably towards the head, and its base has now become elongated, while the second has become still larger and more extended, though still distinct from the caudal posteriorly.

4. In *Phaneropleuron Andersoni* Huxley, from the Upper Old Red of Fifeshire, the two dorsal fins are now fused with each other and with the caudal, forming a long continuous fin along the dorsal margin, while the tail has become nearly diphycercal, with elongation of the base of the lower division of the fin. But the anal still remains separate, narrow, and short-based.

5. In the Carboniferous *Uronemus lobatus* Ag. the anal is now also absorbed in the lower division of the caudal, forming now, likewise on the hæmal aspect, a continuous median fin behind the ventrals. There is also a last and feeble remnant of a tendency to an upward direction of the extremity of the vertebral axis.

6. In the recent *Ceratodus Forsteri* Krefft, the tail is diphycercal (secondary diphycercy), the median fins are continuous, the pectorals and ventrals retain the biserial archipterygium, but the cranial roof-bones have become few.

7. In *Protopterus annectens* Owen, the body is more eel-like, and the paired fins have lost the lanceolate leaflike appearance which they show in *Ceratodus* and the older Dipnoi. They are like slender filaments in shape, with a fringe on one side of minute dermal rays; internally they retain the central jointed axis of the 'archipterygium,' but according to Wiedersheim the radials are gone, except it may be one pair at the very base of the filament.

8. Finally in *Lepidosiren paradoxa* Fitz. the paired fins are still more reduced, having become very small and short, with only the axis remaining.

From this point of view, then, *Dipterus*, instead of being the most specialised Dipnoan, is the most archaic, and the modern *Ceratodus*, *Protopterus*, and *Lepidosiren* are degenerate forms, and instead of the Crossopterygii being the offspring of *Dipterus*-like forms, it is exactly the other way, the Dipnoi owing their origin to Holoptychiidæ, which again are a specialisation on the Rhizodontidæ, though they did not survive so long as these in geological time. Consequently the *Ceratodus* limb, with its long median segmented axis and biserial arrangement of radials, is not an archypterygium in the literal sense of the word, but a derivative form traceable to the short uniserial type in the Rhizodonts. But from what form of fin *that* was derived is a question to which palæontology gives us no answer, for the progenitors of the Crossopterygii are as yet unknown to us.

Plausible and attractive as this theory undoubtedly is, and though it relieves the palæontologist from many difficulties which force themselves upon his mind if he tries to abide by the belief that the Dipnoan form of limb had a selachian origin, and was in turn handed on by them to the Crossopterygii, yet it is not without its own stumbling-blocks.

First as to the dentition, on which, however, M. Dollo does not seem to put much stress, it is impossible to derive *Dipterus directly* from the Holoptychiidæ, unless it suddenly acquired, as so many of us have to do as we grow older, a new set of teeth. The dendrodont dentition of *Holoptychius* could not in any way be transformed into the ctenodont or ceratodont one of *Dipterus*: both are highly specialised conditions, but in different directions. Semon has recently shown that the tooth-plates of the recent *Ceratodus* arise from the concrescence of numerous small simple conical teeth, at first separate from each other.[1] Now this stage in the embryo of the recent form represents to some extent the condition in the Uronemidæ of the Carboniferous and Lower Permian, which stand quite in the middle of Dollo's series.

Again, the idea of the origin of the Dipnoi from the Crossopterygii in the manner sketched above cuts off every thought of a genetic connection between the biserial archipterygium in them and in the Pleuracanthidæ, so that we should have to believe that this very peculiar type of limb arose independently in the Selachii as a parallel development. It may be asked, Why not? We may feel perfectly assured that the autostylic condition of the skull in the Holocephali

[1] 'Die Zahnentwickelung des *Ceratodus Forsteri*.' Jena, 1899.

arose independently of that in the Dipnoi, as did likewise a certain amount of resemblance in their dentition. But those who from embryological grounds oppose any notion of the origin of the Dipnoi from 'Ganoids' might here say, if they chose, If so, why should not also the same form of limb have been independently evolved in Crossopterygii?

Accordingly, while philosophic palæontology is much indebted to M. Dollo for his brilliant essay, and though we must agree with him in many things, such as that the Crossopterygii were not derived *from* the Dipnoi, and that the modern representatives of the latter group are degenerate forms, yet as to the *immediate* ancestry of the Dipnoi themselves, and the diphyletic origin of the so-called archipterygium, we had best for the present keep an open mind.

In his 'Catalogue of the Fossil Fishes' in the British Museum (vol. ii. 1891) Dr. Smith Woodward, following the suggestion of Newberry in 1875, classified the Coccosteans or 'Arthrodira' as an extremely specialised group of Dipnoi. At first I was much taken with that idea, but after looking more closely into the subject I began to doubt it extremely. My own opinion at present is that the Coccosteans are Teleostomi belonging to the next order, Actinopterygii; but Prof. Bashford Dean, of New York, will not have them to be even 'fishes,' but places them in a distinct class of 'Arthrognatha,' which he places next to the Ostracophori (=Ostracodermi), even hinting at a possible union with them, whereby the old 'Placodermata' of McCoy would be restored. It will, therefore, be better to leave them out of consideration for the present, pending a thorough re-examination of their structure and affinities.

We come then to the great order of Actinopterygii, to which a large number of the fishes of later Palæozoic age belong, as well as the great mass of those of Mesozoic, Tertiary, and Modern times. Of these we first take into consideration the oldest sub-order, namely, the Acipenseroidei or Sturgeon tribe, in which the dermal rays of the median fins are more numerous than their supporting ossicles, while the tail is, in most, completely heterocercal. And the oldest family of Acipenseroids with which we are acquainted is that of the Palæoniscidæ, which, in addition to well-developed cranial and facial bones, has the body normally covered with rhombic ganoid scales furnished with peg-and-socket articulations. Of this family one genus, *Cheirolepis,* appears in the same Devonian strata (Orcadian series) with the earliest known Crossopterygii, and of its immediate ancestry we know no more than we do of theirs. *Cheirolepis* is a fully evolved palæoniscid, as shown by its oblique suspensorium, wide gape, and other points of its structure. In the Lower Carboniferous rocks of Scotland, where the family attains an enormous development, we find one or two genera, *e.g. Canobius,* which appear less specialised, as the suspensorium is nearly vertical, and the mouth consequently smaller.

This family endures up to the Purbeck division of the Jurassic formation, and in the Carboniferous *Cryphiolepis,* the Lower Permian *Trissolepis,* and the Jurassic *Coccolepis* we find the same degeneration of the rhombic scales into those of a circular form and imbricating arrangement, which we find repeated in other groups of 'Ganoids.' In fact, in one Carboniferous genus, *Phanerosteon,* the scales disappear altogether with the exception of those on the body prolongation in the upper lobe of the caudal fin, and a few just behind the shoulder-girdle.

And in these Palæozoic times we notice also a side branch of the Palæoniscidæ, constituting the family Platysomidæ, in which, while the median fins acquire elongated bases, the body becomes shortened up and deep in contour. The scales become high and narrow, their internal rib and articular spine coincident with the anterior margin; the suspensorium, too, instead of swinging back as in the typical Palæoniscidæ, tends to be directed obliquely forward, while the snout becomes simultaneously elongated in front of the nares.

A most interesting series of forms can be set up, beginning with *Eurynotus,* which, though it has the platysomid head contour and a long-based dorsal, has only a slight deepening of the body, and still retains the palæoniscid squamation and a short-based anal fin. In *Mesolepis,* which resembles *Eurynotus* in shape, being only slightly deeper, we have now the characteristic platysomid squamation,

and the base of the anal fin is considerably elongated. *Platysomus* has a still more elongated anal fin, and the body is rhombic; while in *Cheirodus* the body is still deeper in contour, with peculiar dorsal and ventral peaks, long fringing dorsal and anal fins, while the ventrals seem to have disappeared altogether. Here also, as in the allied genus *Cheirodopsis*, the separate cylindro-conical teeth characteristic of the family are, on the palatal and splenial bones, replaced by dental plates, reminding us of those of the Dipnoi. Certainly the Platysomidæ seem to me to form a morphological series telling as strongly in favour of Descent as any other in the domain of palæontology.[1]

If we now return to the Palæoniscidæ we find that they dwindled away in numbers in the Jurassic rocks, and finally became extinct at the close of that epoch. But already in the Lias (leaving the Triassic Catopteridæ out of consideration for the present) we find that they have sent off another offshoot sufficiently distinct to be reckoned as a new and separate family, namely, the Chondrosteidæ, in which the path of degeneration, in all but the matter of size, seems to have been entered on.

In the genus *Chondrosteus*, though the palæoniscid type is clearly traceable in the cranial structure, there is marked degeneration as regards the amount of ossification, and though the suspensorium is still obliquely directed backward the toothless jaws are comparatively short, and the mouth seems now to have become tucked in under the snout as in the recent sturgeon. Then the scales have entirely disappeared from the skin except on the upper lobe of the heterocercal caudal fin, where they are still found arranged exactly as in the Palæoniscidæ.

Chondrosteus in fact conducts us to the recent Acipenseroids—the Polyodontidæ (Paddle-fishes) and Acipenseridæ (Sturgeons).

The first of these resembles *Chondrosteus* in the nakedness of the skin, except on the upper lobe of the caudal fin,[2] the more palæoniscid aspect of the external cranial plates, such of them as remain, for they are now still further reduced. But in front of the mouth and eyes there is an addition in the form of an enormous vertically flattened paddle-shaped snout covered above and below with a large number of small ossifications.

The sturgeons have, however, nearly altogether lost the palæoniscid arrangement of the cranial roof-bones, which, strange to say, now exhibit an arrangement reminding us of that in *Dipterus*, and the external facial plates are still more reduced than even in *Polyodon*; but we may note a very strong resemblance to *Chondrosteus* in the position of the mouth, the edentulous jaws, and the jugal bone, indeed also in the palatal apparatus.

So the sturgeons and paddle-fishes of the present day would seem to be the degenerate, though bulky, descendants of the once extensively developed group of Palæoniscidæ, even as the modern Dipnoi are degenerated from those of Palæozoic times.

We now notice another *apparent* offshoot of the Palæoniscidæ, namely, the family of Catopteridæ (*Catopterus* and *Dictyopyge*), which is limited to rocks of Triassic age. Unfortunately the osteology of the head is not well known, but Dr. Smith Woodward's observations are to the effect that both the head and shoulder-girdle are of palæoniscoid type. The relationship of these small fishes to the Palæoniscidæ is shown by the general shape, the number and position of the fins, the rhombic ganoid scales, and the close arrangement of the rays of the median fins. But the rays of the dorsal and anal fins are now almost equal in number to their supporting ossicles, and the tail has become only abbreviate heterocercal. That is to say, the caudal body prolongation no longer proceeds to the termination of the upper lobe, which is reduced in size and in the number of its rays. The

[1] R. H. Traquair, 'Structure and Affinities of the Platysomidæ,' *Trans. Roy. Soc. Edin.* xxix. 1879, pp. 343–391.

[2] Collinge has, however, found rudimentary scales in the skin of the recent *Polydon folium* (*Journ. Anat. and Phys.* ix. pp. 485–487), and Cope has described an allied Eocene genus, *Crossopholis*, in which minute scales are seen (*Mem. Nat. Acad. Sciences*, iii. 1886, pp. 161–163).

Catopteridæ are obviously an annectent group, as, although from their abbreviate heterocercal tail they have usually been placed in the next sub-order, Dr. Smith Woodward prefers to look upon them as Chondrostei (*i.e.* Acipenseroidei).[1] Wherever we place them they express the beginning of a set of changes towards a more modern type of fish, which are emphasised in the great series of Lepidosteoid fishes (Protospondyli + Ætheospondyli of Smith Woodward), being the fishes more or less allied to the recent Bony Pike of North America.

But these changes must have been well advanced before the Triassic era, for already in the Upper Permian occurs the genus *Acentrophorus,* whose fellowship with *Semionotus, Lepidotus,* and all the rest of the series of Mesozoic semi-heterocercal 'Ganoids' is at once obvious.

If we look at the configuration of a typical Jurassic member of this series, such as *Lepidotus* or *Eugnathus,* we shall at once see that we are a stage nearer the modern osseous fish. Though the scales are bony, rhombic, and ganoid, we are struck by the 'Teleostean'-like aspect of the external bones and plates of the head, the rays of the dorsal and anal fins are fewer and correspond in their number to that of the internal supports or 'interspinous' bones, while in the caudal we see again the semi-heterocercal or abbreviate-heterocercal condition we noticed above in *Catopterus.*

Then if we refer to the tail of *Lepidosteus* itself we shall observe how few are its rays and how evident it is that we have here to do only with the lower lobe of the original palæoniscoid caudal fin. For a convincing corroboration of this we have only to look at the tail of the embryo *Lepidosteus* as described and figured by Prof. A. Agassiz to see that it in reality passed through an Acipenseroid stage, and the last we see of the upper lobe of this tail is in the form of a filament which projects from the top of the original lower lobe and then disappears.

Again, in these Lepidosteid forms we have a repetition of the same tendency for the thick rhombic peg-and-socket articulating scales to become rounded and imbricating as we saw in the Crossopterygii and again in the Palæoniscidæ. So, for instance, in *Caturus,* which has been shown by Dr. Smith Woodward to resemble *Eugnathus* so closely in structure, the scales are deeply overlapping, and most of them 'cycloidal' in shape. To such an extent does this go that in the recent *Amia,* whose skeletal structure so clearly shows it to belong to this group, the rounded scales are so thin and flexible that after it was removed from the Clupeoid family, or Herrings, and placed among the 'Ganoids,' it was considered to be the type of a distinct sub-order of 'Amioidei.' Ten years ago, however, Dr. Beard came to the conclusion, from anatomical and embryological data, that this division could no longer be maintained, and that the Amioids must in fact be united with the Lepidosteids.[2] Dr. Smith Woodward has, therefore, in the third volume of his catalogue, done well to reduce the 'Amioidei' to the rank of a family, including also the Jurassic genera *Liodesmus* and *Megalurus,* and to place this family close to the Eugnathidæ.

As the Acipenseroids dwindled away after the close of the great Palæozoic era, and are now scantily represented only by the degenerate paddle-fishes and sturgeons, so the Lepidosteid series, flourishing greatly in the Trias and Jura, in their turn declined in the Cretaceous, and in the Tertiary period became about as much a thing of the past as they are now, the North American *Lepidosteus* and *Amia,* of which remains of extinct species have also been found in Eocene and Miocene rocks, only remaining. These two genera can, however, hardly be called 'degenerate.'

But that the fishes which succeeded the Lepidosteids in populating the seas

[1] Dr. Smith Woodward also refers the singular Belonorhynchidæ of the Trias to the same sub-order on account of the excess of the number of the dermal rays of the dorsal and anal over that of their supporting ossicles, even although the tail is here abbreviate diphycercal.

[2] 'The Inter-relationships of the Ichthyopsida,' *Anatomischer Anzeiger,* 1890. Smith Woodward arrived at the same result in 1893 from the study of the Jurassic genera *Lepidotus* and *Dapedius.* See *Proc. Zool. Soc. Lond.* June 20, 1893, pp. 559–565.

and rivers of the globe were evolved from them there can be no reasonable doubt, while it is equally clear that they branched off at an early period, as already in the Trias we find the first representatives of the order of Isospondyli, which contains our familiar Herrings, Salmonids, Elopids, Scopelids, &c. For Dr. Smith Woodward has not only definitely placed the Jurassic Leptolepidæ and Oligopleuridæ in the Isospondyli, but also the Pholidophoridæ, which appear in the Trias and extend to the Purbeck. And it is of special interest that in the Pholidophori the scales are still brilliantly ganoid and mostly retain the peg-and-socket articulation, while in the allied Leptolepidæ, although they have become thin and circular, a layer of ganoine mostly remains.

With the Isospondyli we now get fairly among the bony fishes of modern type—Teleostei as we used to call them—to which other sub-orders are added in Cretaceous and Tertiary times, and which in the present day have assumed an overwhelming numerical preponderance over all other fishes. The prevalent form of scale among these is thin, rounded, deeply imbricating, and with the posterior margin either plain (cycloid) or serrated (ctenoid). But that these 'cycloid' and 'ctenoid' scales are modifications from the rhombic osseous 'ganoid' type we cannot doubt after what we have seen. It is indeed strange that the same tendency to the change of rhombic into circular overlapping scales should have occurred independently in more than one group.

For reasons given at the beginning, and also because I fear I have already exceeded the limit of time usually allotted to such an Address, I must now stop.

But in conclusion I may allude to a well-known fact regarding the tail of these modern fishes, the bearing of which on the doctrine of Descent is sufficiently clear and has long been recognised.

We have seen that the completely heterocercal tail of the typical Acipenseroid becomes, by abortion of the upper lobe and shortening of the axis, the semi-heterocercal one of the Lepidosteids, in most of which, however, the want of symmetry is still perceptible externally by a short projection or 'sinus' of scales which is directed obliquely upward at the beginning of the top of the fin. In the ordinary bony fishes and in some Lepidosteids also the caudal fin becomes likewise symmetrical, as seen from the outside; generally also bilobate, though the upper lobe is not that of a Palæoniscid or Sturgeon. This condition of tail has been long known as 'homocercal.' But in many such homocercal tails, when we dissect away the skin and soft parts, the upward bend of the vertebral axis is revealed, and in some, as in the Salmon, the extremity of the vertebral axis is continued as a cartilaginous style among the rays near the upper margin of the fin. But there are many others, such, for instance, as the peculiarly specialised group of Pleuronectidæ or flat fishes, in which the skeleton of the caudal extremity *looks* quite symmetrical, but yet in the embryo the extremity of the notochord is seen to have an upward bend, showing that the homocercal tail is indeed a specialisation on the old heterocercal one. It is strange that though this embryological fact was long ago pointed out by Agassiz, and though he noted its great interest in connection with the prevalence of heterocercy among the Palæozoic fishes, yet he remained to the end an opponent of evolution. But this is just one of these instances in which Phylogeny and Ontogeny mutually illustrate each other. Why, otherwise, should the tail of the embryo stickleback or flounder be heterocercal?

Incompletely as I have treated the subject, it cannot but be acknowledged that the palæontology of fishes is not less emphatic in the support of Descent than that of any other division of the animal kingdom. But in former days the evidence of fossil ichthyology was by some read otherwise.

It is now a little over forty years since Hugh Miller died: he who was one of the first collectors of the fossil fishes of the Scottish Old Red Sandstone, and who knew these in some respects better than any man of his time, not excepting Agassiz himself. Yet his life was spent in a fierce denunciation of the doctrine of evolution, then only in its Lamarckian form, as Darwin had not yet electrified the world with his 'Origin of Species.' Many a time I wonder greatly what Hugh Miller would have thought had he lived a few years longer, so as to have

been able to see the remarkable revolution which was wrought by the publication of that book.

The main argument on which Miller rested was the 'high' state of organisation of the ancient fishes of the Palæozoic formations, and this was apparently combined with a confident assumption of the completeness of the geological record. As to the first idea, we know of course that evolution means the passage from the more general to the more special, and that although as the general result an onward advance has taken place, yet specialisation does not always or necessarily mean 'highness' of organisation in the sense in which the term is usually employed. As to the idea of the perfection of the geological record, that of course is absurd.

We do not and cannot know the oldest fishes, as they would not have had hard parts for preservation, but we may hope to come to know many more old ones, and older ones still, than we do at present. My experience of the subject of fossil ichthyology is that it is not likely to become exhausted in our day.

We are introduced at a period far back in geological history to certain groups of fishes some of which certainly are high in organisation as animals, but yet of generalised type, being fishes and yet having the potentiality of higher forms. But, because their ancestors are unknown to us, that is no evidence that they did not exist, and cannot overthrow the morphological testimony in favour of evolution with which the record actually does furnish us. We may therefore feel very sure that fishes, or 'fish-like vertebrates,' lived long ages before the oldest forms with which we are acquainted came into existence.

The modern type of bony fish, though not so 'high' in many anatomical points as that of the Selachii, Crossopterygii, Dipnoi, Acipenseroidei, and Lepidosteoidei of the Palæozoic and Mesozoic eras, is more specialised in the direction of the fish proper, and, as already indicated, specialisation and 'highness' in the ordinary sense of the word are not necessarily coincident. But ideas about these things have undergone a wonderful change since those pre-Darwinian days, and though we shall never be able fully to unravel the problems concerning the descent of animals, we see many things a great deal more clearly now than we did then.

The following Reports were read:—

1. *Report on the Bird Migration in Great Britain and Ireland.*
See Reports, p. 403.

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2. *Report on the Occupation of a Table at the Zoological Station, Naples.*
See Reports, p. 380.

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3. *Report on the Occupation of a Table at the Marine Biological Laboratory, Plymouth.*—See Reports, p. 399.

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4. *Report on the 'Index Animalium.'*—See Reports, p. 392.

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5. *Interim Report on the Plankton and Physical Conditions of the English Channel.*—See Reports, p. 379.

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6. *Tenth Report on the Zoology of the Sandwich Islands.*
See Reports, p. 398.

FRIDAY, SEPTEMBER 7.

The following Papers were read:—

1. *The Miocene Fauna of Patagonia. By* Professor W. B. SCOTT.

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2. *The Nesting Habits of* Ornithorhynchus. *By* Dr. GREGG WILSON.

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3. *Malaria and Mosquitoes. By* Major RONALD ROSS.

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4. *The Nuclei of Dendrocometes.*
By Professor S. J. HICKSON, *M.A., D.Sc., F.R.S.*

Plate denied the existence of true 'Nebenkerne,' or micronuclei, in Dendrocometes, and Schneider was unable to prove their existence. There can be no doubt, however, that such bodies do occur, and I have been able by the improved methods of preservation and staining to trace all the important stages of their mitosis. Maupas asserted that in the Suctoria there is only one micronucleus, and that it is very small. If this is true of the Suctoria generally, Dendrocometes is exceptional, as there is reason for believing that at least two and sometimes three or four micronuclei occur, each of which is as large as or larger than the micronuclei of *Paramœcium caudatum.* During conjugation one micronucleus from each individual passes down the connecting bar, and there can be no doubt that a fusion of micronuclei occurs, although the whole series of stages of this process has not yet been observed.

The macronuclei of the conjugating individuals are very much elongated and pointed at their extremities. In several cases I have observed that one end of the macronucleus of each conjugating individual passes down the connecting bar, and in one specimen an actual fusion of the two macronuclei was seen.

It would be premature to discuss the meaning of this conjugation of the macronuclei at present, but there can be no doubt of the bearing of this fact upon the prevalent view that the conjugation of Infusoria is entirely an affair of micronuclei. At the end of conjugation the macronucleus disintegrates, as in the Ciliata. The new macronucleus, which makes its appearance during the early stages of the disintegration of the old macronucleus, is at first clear, homogeneous, and almost devoid of chromatin. The chromatin accumulates in it as the fragments of the old macronucleus disintegrate.

The structure of the macronucleus has been very carefully reinvestigated. Details of the results will be published later, but it may be stated here that the division of the macronucleus during gemmation is purely amitotic. There are no centrosomes and no achromatic spindle.

In this investigation I have been very materially assisted by Mr. T. J. Wadsworth, of the Owens College laboratory.

The iron hæmatoxylin method of staining has been principally used, but valuable results have also been obtained by a new method of using brazilin with iron-alum.

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5. *Cyclopia in Osseous Fishes. By* JAMES F. GEMMILL, *M.A., M.D.*

In this paper an outline is given of the anatomy of some cyclopean trout embryos; the conditions present are contrasted with those which are found in similar cases among the higher animals, and their general bearing is briefly discussed.

Summary of Chief Points relating to Cyclopia in the Trout.

1. In all the specimens examined distinct olfactory organs and nerves of reduced size are present.

2. Dropsy of the central cavities of the brain or of the meninges is remarkable for its absence. The cerebral lobes are more or less united, but they may attain a very fair degree of development. Pineal growths are present as in the normal condition.

3. *Trabeculæ cranii* of full length are present, but they bend downwards so as to lie below the cyclopean eye or pair of eyes. They are closely fused together anteriorly to form a single median bar, the appearance of which suggests that in this region they have never been separate.

4. In some of the specimens examined cyclopia is associated with absence of the mouth opening and great shortening of the lower jaw arch.

In these cases the infundibulum and the whole pituitary body are absent, the basal masses of the mid-brain are more or less fused together, the optic nerves are rudimentary or absent, and the eyes, though they have a well-developed retina and choroid, have no choroidal fissure. The auditory labyrinths and capsules on either side as well as the suspensorial cartilages remain, however, almost as widely separate as in the normal condition.

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6. *On some Causes of Brain-configuration in the Brain of Selachians. By* Professor R. Burckhardt.

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7. *On the Systematic Value of the Brain in Selachians. By* Professor R. Burckhardt.

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8. *On some Points in the Life-History of the Littoral Fishes. By* Professor W. C. McIntosh, *F.R.S.*

No group of marine fishes is better fitted for the demonstration of the great mortality which ensues between the period of the deposition of the eggs and the attainment of the adult condition than the littoral fishes, such as the shanny, viviparous blenny, sea-scorpion, lumpsucker (*partim*), gunnel, fifteen-spined stickleback, and the five-bearded rockling. The adults, for instance, of the shanny can, as a rule, be readily located in the pools between tide-marks on rocky shores. The adult female deposits a considerable number of eggs in small rocky caverns, and the pelagic young abound in the tidal pools in August and September. As they increase in size they become fewer, not by spreading themselves in the ocean or by taking advantage of new sites amongst the rocks, but by steady diminution from the attacks of other predatory forms. One or two adults alone survive in each suitable rock-pool. In the group under consideration the conditions of the species are various, the majority, however, having demersal eggs, which in the case of the gunnel are protected by the parents, and in the fifteen-spined stickleback are sheltered in a nest, whilst the rockling has pelagic eggs, and the viviparous blenny produces living young fully two inches in length. The result is nearly the same in each case, for the adults do not, as a rule, vary much from period to period. A comparatively large number of eggs and young are necessary to maintain the species, even though in our country there is no systematic capture of any of them either for food or pleasure.

SATURDAY, SEPTEMBER 8.

The following Reports and Papers were read:—

1. *Report on the Physiological Effects of Peptone and its Precursors when introduced into the circulation.*—See Reports, p. 457.

2. *On a Peptic Zymase in Young Embryos.*
By Marcus Hartog, *M.A., D.Sc., F.L.S.*

In 1896 I communicated to the Association a note in which I referred incidentally to the discovery of a peptic zymase in the embryo of the frog at a stage when the macromeres appear as a white plug in the region of the blastopore, in the entire embryo of the chick after twenty-four hours, and in the extravascular blastoderm after three days' incubation. These observations were made by the classic method of killing and coagulating with absolute alcohol, drying and powdering, extracting with glycerine, precipitating with absolute alcohol, and ascertaining the properties of this precipitate on boiled white of egg and boiled blood-fibrin. In successive years I obtained only negative results. A hint from Professor J. Reynolds Green gave me the explanation of these contradictory results. In 1896 I had the valuable assistance of Mr. E. J. Butler, and was able to carry through each series of experiments continuously; while in the three following years they were protracted indefinitely. This spring I was able to confirm my original results, changing my methods to avoid delay and consequent loss of zymase. The objects themselves were killed in chloroform- or thymol-water and pounded; and instead of using other substances for digestion I contented myself with the abundant material of the vitelline granules present in each case within the cell.

I relied in all cases on the 'biuret test' of Piotrowsky, consisting in warming the product of digestion (after neutralising, boiling, and filtering to remove all acid-albumen) with strong caustic alkali and a trace of copper sulphate; the pink coloration reveals the presence of albumoses or peptones. On some occasions the chick-blastoderm tests turned yellowish brown as the temperature continued to rise, and on boiling there was an abundant dark precipitate, indicating the presence of a reducing body. A zymase capable of yielding such a product has recently been described by Müller, who, however, has only found it active in neutral liquids.

No trace of any other ferment has been found so far; it is noteworthy that all observers are agreed in the recognition of a *peptic ferment only* in the holozoic Protista.

Frog embryos kept in thymol water in a stoppered jar in the dark—in a closed locker—for a month had lost all digestive properties.

Two important conclusions appear to follow:—

1. In all plants, so far as is known, it has been shown that the cell cannot directly utilise the reserves that it contains, but only the products of their hydrolysis; and this hydrolysis is not a function of the living protoplasm itself, but of the zymases it forms, since the process can be reproduced in vitro working with the killed cell or its extract. It would seem almost certain that the same law holds good for the animal cell.

2. These facts explain the apparent exception to the law of division at the doubling of the volume formulated by Herbert Spencer, as I indicated in my note of 1896. A cell that instead of growing by its protoplasm only accumulates reserve material has no need to constantly readjust its surface to its volume. When, however, the formation of a zymase enables it to utilise its reserves, and its protoplasm grows at the expense of the products of their digestion, the need for augmented surface asserts itself, and we get the repeated cell-divisions so marked in the 'segmentation' of the embryo and in other cases of brood-formation. It follows also that two distinct processes have been compounded under the single term of 'anabolism:' (*a*) the building up and storage of reserves; (*b*) the growth of the protoplasm at the expense of nourishment from without, or the digestion of the reserves within. From this point of view the segmentation of the embryo is certainly an *anabolic* process of the second category, and not mainly catabolic, as usually stated.

3 *On the Mechanical and Chemical Changes which take place during the Incubation of Eggs.* By R. Irvine, *F.C.S.*

Six hen's eggs were hatched in the usual manner. These eggs were weighed daily. The loss of weight was progressive during the twenty-one days of hatching, ranging from

in No. 1	0·34 gramme
„ 2	0·36 „
„ 3	0·25 „

on the first day to a maximum of

in No. 1	0·50 gramme
„ 2	0·55 „
„ 3	0·36 „

on the twenty-first day, the loss being proportional to their size and weight, the total loss during the twenty-one days being

in No. 1	7·94 grammes
„ 2	8·46 „
„ 3	5·61 „

when the chicks chipped the shells and began life on their own account.

The other three eggs were not fertile, but during the twenty-one days lost weight also, on the first day losing

in No. 4	0·23 gramme
„ 5	0·30 „
„ 6	0·33 „

the loss in No. 4 reaching 0·30 gramme on the 21st day
„ „ 5 „ 0·47 „ „ „
„ „ 6 „ 0·32 „ „ „

the totals being

No. 4	5·34 grammes
„ 5	7·44 „
„ 6	7·38 „

The average weight of each of the fertile eggs was 56·93 grammes, falling to 49·55 grammes on the day before the chicks liberated themselves from the shells. Thus the average loss sustained by each egg was 7·38 grammes, or 12·96 per cent; so that the average loss per egg per day was 0·35 per cent.

As the results from the unfertile eggs were useless for comparison, a fresh egg was employed to determine the weight of water and solid matter respectively.

The egg weighed	58·40 grammes
The shell and membrane (moist, 6·92)	5·80 „ dry)
The weight of yolk, albumen, and water in egg and membrane was	52·60 „

51·45 grammes of the egg were dried at 101° C., and gave of

Dry matter	13·18 grammes, or per cent.	25·617
Moisture	38·27 „ „ „	74·383
		100·000

A newly hatched chick, weighing 40·8 grammes, was dried in the same manner, and after the moisture had been driven off there was left

Dry matter	10·9 grammes, or per cent.	26·715
Moisture	29·9 „ „ „	73·285
		100·000

These results are curious and interesting, for they seem to show that the proportions of water and solid contents are practically the same in the fresh egg and in the newly hatched chicken.

Ultimate analyses were made of the dry matter contained in the fresh egg and in the dried chicken. After deducting the weight of the shell and water from the total weight of the egg, there remained 13·21 grammes of dry matter. This gave on analysis

Ash	0·568 gramme, or per cent.	4·30 of dry matter
Nitrogen . . .	1·171 " " "	8·87 " "
Hydrogen . . .	1·202 " " "	9·10 " "
Oxygen . . .	2·295 " " "	17·38 " "
Carbon . . .	7·972 " " "	60·35 " "
	13·208 grammes	100·00 per cent.

The same method of analysis showed the dried chicken to consist of

Ash	0·676 gramme, or per cent.	6·20 of dry matter
Nitrogen . . .	1·091 " " "	10·00 " "
Hydrogen . . .	0·892 " " "	8·18 " "
Oxygen . . .	2·261 " " "	20·62 " "
Carbon . . .	6·000 " " "	55·00 " "
	10·920 grammes	100·00 per cent.

Results.

Ash was raised by	1·90 gramme per cent.
Nitrogen was raised by	1·13 " "
Hydrogen was lowered by	0·92 " "
Oxygen was raised by	3·24 " "
Carbon was lowered by	5·35 " "

The increase of ash in the chicken is obviously due to lime being absorbed from the shell, and combined with phosphorus present in the yolk.

The increase of nitrogen (equal to 1·13 per cent.) is apparently due to the decrease of carbon. This also applies to the increase of oxygen. The decrease of carbon (5·35 per cent.) and hydrogen (0·92 per cent.) is due to their oxidation, and may be (in part) accounted for as carbonic acid and water passing through the shell during incubation.

Seemingly we have a rearrangement of the elements above named, and the fact established that water becomes altered into potential living matter, representing the tissues and feathers of the living bird, &c., whilst the ash is also increased by the abstraction of lime from the shell, combined with the phosphorus derived from the yolk during the hatching process.

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4. *On the Physiological Effect of Local Injury in Nerve.*
By Professor F. Gotch, *F.R.S.*

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5. *Report on the Comparative Histology of the Suprarenal Capsules.*
See Reports, p. 452.

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6. *Report on the Vascular Supply of Secreting Glands.*
See Reports, p. 458.

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7. *Report on Electrical Changes in Mammalian Nerve*
See Reports, p. 455.

8. *Report on the Comparative Histology of Cerebral Cor ex.* See Reports, p. 453.

9. *Report on the Micro-chemistry of Cells.*—See Reports, p 449.

10. *Observations on the Development of the Cetacean Flipper.* *By* Professor JOHNSON SYMINGTON.

11. *The Articulations between the Occipital Bone and Atlas and Axis in the Mammalia.* *By* Professor JOHNSON SYMINGTON.

MONDAY, SEPTEMBER 10.

The following Papers and Report were read:—

1. Mnestra parasites, *Krohn.* *Preliminary Account.* *By* R. T. GÜNTHER, *M.A.*, *F.R.G.S.*, *Magdalen College, Oxford.*

During the spring of the present year the prevailing westerly winds no doubt contributed to the fact that an unusually large number of *Phyllirhoë bucephala* were captured in the Bay of Naples. I examined every specimen I could get hold of and found that of thirty-one individuals of Phyllirhoë taken between March 28 and April 20 nineteen, or more than half, had a Mnestra adhering to them. My friend Cavaliere Lo Bianco in the kindest way placed his store of spirit-preserved material at my disposal for examination. Unfortunately the dates of capture were not noted, but of forty-three Phyllirhoë every one had or had had a Mnestra upon it.

From this relative abundance of the parasite it follows that the reproductive power of the Mnestra must be far and away in excess of that of the *Phyllirhoë bucephala* of the Bay of Naples. Indeed, the fertility of Mnestra must, one would think, be greater than is usual even among parasites. It is therefore most remarkable that hitherto the method of the propagation of Mnestra should have remained undiscovered. We do not know whether it reproduces itself by a sexual or an asexual process, by eggs or budding.

It was in consequence of our ignorance of this point that systematists have not been able to assign Mnestra to its proper place in the system of Haeckel—which primarily depends upon the place of development of the genital cells in the Medusa.

I have, however, been fortunate enough to discover other characteristics of the Mnestra which will enable us to unhesitatingly affirm that it should be classed with the *Cladonemidæ,* a family of the Anthomedusæ.

The Mnestra is attached to the Phyllirhoë by its manubrium, which is comparatively short and serves the purpose of obtaining nutriment, apparently by sucking the blood of the host. The *shape* of the body of the Mnestra varies greatly. The margin of the umbrella is sometimes notched, but this marginal notch is by no means so constant in its presence as to justify us in regarding it as Claus[1] did, a characteristic of Mnestra. The shape of the Medusa can be well described as that of a bun with a large inpushing or 'dimple' in the middle of the exumbral surface, from which, in typical cases, four furrows proceed interradially to the margin. It is by the intensification of one of these grooves that the notch of Claus is often produced. The symmetry of the velum and circular canal is generally not much affected by these furrows on the surface of the ex-umbrella.

The *tentacles* are four in number. The majority of specimens examined had two reduced to mere knobs, and some had three or even all the tentacles reduced to this condition. It seemed to me that the reduction of the tentacle was a mark

[1] Claus, *Verh. Zool. Bot. Inst.*, Wien, xxv, 1876.

of old age. A well-developed tentacle of Mnestra is a compound tentacle of undoubted Cladonemid type. The base is swollen and simple, but the distal portion is slender and tapering, with a row of small stalked multinucleate club-shaped bodies along the entire length of one margin. These bodies contain nematocysts, and they are undoubtedly homologous with the stalked clubs containing thread cells of many of the Cladonemid genera.

A further point of resemblance between *Mnestra parasites* and certain of the Cladonemidæ is in the fact that there is a circular tract of nematocysts arranged round the umbrella margin, close to the circular canal, and from this circular tract extend four centripetal tracts along the perradii of the ex-umbrella. These perradial tracts usually extend as far as the exumbral 'dimple' and sometimes continue down into it.

The gastro-vascular system is of the usual type. There are a central stomach, four radial canals, and a circular canal. The stomach is of an irregular shape and is often provided with irregular diverticula in which corpuscles which originally belonged to the blood of the Phyllirhoë may sometimes be seen. The mouth is clogged with endoderm cells with intercellular spaces through which the organism imbibes its nutriment.

Among the 100 odd individuals examined a number of varieties and abnormal forms were observed. A description of these as well as the histology of Mnestra will shortly be published in the Naples 'Mittheilungen.'

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2. *The Respiration of Aquatic Insects. By* Professor L. C. Miall, *F.R.S.*

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3. *The Tracheal System of* Simulium : *a Problem in Respiration. By* T. H. Taylor.

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4. *The Pharynx of* Eristalis. *By* J. J. Wilkinson.

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5. *The Structure and Life History of the Gooseberry Sawfly. By* N. Walker.

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6. *Report on the Coral Reefs of the Indian Region.*—See Reports, p. 400.

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7. *Contributions to the Anatomy and Systematic Position of the Læmargidæ. By* Professor R. Burckhardt.

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8. *On the Nestling of* Rhinochetus. *By* Professor R. Burckhardt.

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9. *The Dentition of the Seal. By* R. J. Anderson, *M.A., M.D., Professor of Natural History, Galway.*

The dentition of the common seal is generally understood to be in the great majority of cases $\frac{3}{2}$ I., $\frac{1}{1}$ C., $\frac{4}{4}$ P.-m., $\frac{1}{1}$ M. There may be an additional premolar, due to the persistence of one of the milk-teeth. The molars are not too much crowded in the upper jaw, but more so in the lower. The incisors have standing room, but the central of the lower jaw show a disposition to stand back; the small platform on which the latter seem to stand narrows anteriorly, and the sockets are deeply sunk in front of this plane. The four incisors of the lower jaw correspond to the

inner four of the upper jaw when the teeth are met, and are about the same size as these latter, whilst the two upper lateral incisors are larger than the inner two, but are far removed from the canines both in position and size. The comparison of the dentition of the seal with that of the polecat, the grison, and especially the otter, is instructive. The badger may be said to occupy a place between bears and weasels, and the upper incisors have carnivor type, formula, and arrangement. In the upper set the incisors are not embarrassed, although they stand three abreast on each side, as in better marked carnivors. In the badger the intermediates in the lower jaw stand back out of range, as in Putorius and Galictis. In the upper jaw of the otter the incisors are in range, but the second incisors of the lower jaw stand back, as if the teeth were crushed up. It is noteworthy that the first premolar of the upper jaw in this animal is placed internal to the canine, while the first premolar of the lower jaw is placed at an interval behind the canine.

All the molar teeth of the common seal except the first are well known to have two fangs; as regards the cusps, the precise arrangement is not generally stated. The cusps of the upper molars fit into intervals between the cusps of one lower molar or of separate adjacent molars. The first premolar has a large front cusp with a shoulder (an approach to the formation of a cusp) in front, and a small cusp behind. A slight groove passes forwards and inwards, marking off an enamelled surface internal to the cusps. The second upper premolar has a large central cusp, a shoulder in front and to the inner side of this; and two cusps, one immediately behind the larger and one still farther back. The third premolar has a shoulder in front and internal to a large cusp; then there are two smaller cusps in succession to this posteriorly. The fourth has a blunter chief cusp, slight irregularities on the inner shoulder, and a second cusp, with an attempt at the formation of a third cusp still farther back; this tooth is more like the last molar of the otter than the previous teeth are. The molar has a large middle cusp, with a slightly smaller one behind it and a small cusp anteriorly. The *first* lower premolar has three cusps; the anterior is the smallest, and the central one next. The cusps are placed near the outer surface of the tooth; internal to and behind the middle one is an elevation suggestive of a fourth cusp. The *second* premolar has a large central cusp curved somewhat back, a small cusp in front of this, and two behind; there is a platform internal to the cusps. The *third* premolar has *four* cusps: the front cusp small, the second the largest and turned back, the two posterior smaller. The *fourth* premolar has five cusps: two small ones in front of the large one, and two behind it; the central cusp is bent back. The molar has one cusp in front of and two behind the central cusp, which is not prominent. This tooth is very small, and has a bulging opposite each of the first three cusps. The contrast in the comparison of the incisors of the lion, hyæna, and dog with those in the lower jaw of the badger, the polecat, and otter is well worth noting. In the otter there would not be room for the intermediate (second) incisor to stand in rank. The second incisors in the bear stand somewhat back, but the sockets are placed behind the level of the third pair of incisors. It may seem likely that the habits of the badger and weasel should render a narrow lower jaw desirable anteriorly, but it is not clear that the otter would be well served by the same device. The lower jaw of a very young seal which was examined has lost the lower incisors, but the sockets are suggestive of a nearer approach to the otter arrangement.

Halichærus grypus has the same dental formula as the common seal. The last molar of the upper jaw is at some distance from the other back teeth, which are all pointed with single cusps. In some, however, there is a shoulder suggestive of a second cusp. This is the case in the last lower, where a slight indication of a cusp exists behind the pointed cone. A furrow is visible on the outer sides of the third and fifth lower and second and fifth upper. The lower canines extend between the upper corner incisors and the upper canines, which are about the same length as the corner incisors, but much thicker.

The following animals have the intermediate incisor behind the inner and outer, either from base to apex or at the base alone:—Paradoxurus, Ailurus, Herpestes mungos, Lutra, Galictis, Gulo, Conepatus, Brown Bear, the Malayan Bear, Snow Bear, Polar Bear, and Ursus collaris; Melursus not, Arctoidotherium

Bonariense, Gerv., behind at base, between at apex. In Ursus spelæus behind. Australian Sea-lion, Otaria pusella, O. stelleri, O. jubata, I. $\frac{3}{2}$. Elephant Seal, I. $\frac{3}{1}$. Crab-eating Seal, Monachus, and Onomatophora, I. $\frac{2}{2}$. The innermost is far back in the last. In Felis tigris the inner and in F. macroscelides the inner and intermediate incisors are somewhat back.

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10. *Note on Exhibition of Skulls of Antarctic Seals.* *By* G. E. H. BARRETT-HAMILTON.

I am indebted to the authorities of the British Museum of Natural History for the opportunity of studying the collection of seals brought home from the antarctic seas by the *Belgica*, and now the property of the 'Expédition Antarctique Belge.'

The collection is not a large one, and consists almost entirely of specimens of the *Phocidæ*, the *Otariidæ* being represented by only one very immature skull.

One of the main points of interest regarding the specimens is the fact that they afford no support whatsoever to the supposition, sometimes advanced, that some startlingly new forms of marine *Carnivora* will be found to occur in the antarctic seas. All the species known to occur in these seas, except the (perhaps extinct) sea elephant, are represented in the collection. Thus there are skulls of *Leptonychotes weddeli*, *Ogmorhinus leptonyx*, *Lobodon carcinophaga*, and *Ommatophoca rossii*; but all these are framed on patterns so close to those of the older specimens in the British Museum that it is impossible (with the present material) to find even new sub-specific differences amongst them. At the same time it is highly interesting to have a series of specimens of various ages from which to amplify our knowledge of the various forms.

Probably the most interesting species represented in the collection is *Ommatophoca rossii*, of which there are two skulls. These are remarkable for the variability of their dentition; a point to which [1] Mr. W. Bateson has already drawn attention with reference to the only two previously known skulls. It seems now certain that variability of dentition must be regarded as one of the characteristics of Ross's seal, and it is interesting to know that this variability is not shared by the other species of antarctic *Phocidæ*, all the specimens which I have examined being quite uniform and showing no abnormalities.

I hope at a later date to publish a more detailed account of these skulls. The following were exhibited at the Section:—*Ommatophoca rossii* (two skulls) and *Lobodon carcinophaga*.

TUESDAY, SEPTEMBER 11.

The following Papers were read:

1. *Photographs of some Malayan Insects.*[2] *By* NELSON ANNANDALE.

The photographs were taken from living insects in the Siamese Malay States last year. The first represented a *Stauropus* larva not dissimilar to the English Lobster Caterpillar on its food-plant, *Melastoma polyanthum*—the so-called 'Straits Rhododendron.' When it is about to change its skin this larva resembles a bird's dropping, and is then sluggish in its movements; but after the ecdysis has taken place, the insect becomes active again, and keeps its true legs and the processes on the posterior region of its abdomen in constant agitation. Its colour also changes considerably.

The second photograph represented a portion of the stem of a living Areca-palm, with a small Geometrid caterpillar that conceals itself by plastering fragments of a powdery lichen upon its own back.

The third and fourth photographs showed two species of a peculiar type of larva, supposed to belong to Lycid beetles, and noticeable for its flattened body, minute

[1] *P.Z.S.*, 1892, pp. 106, 107.

[2] For details see *Proc. Zool. Soc.*, London, Nov. 1900.

retractile head, and for the processes that project in a series along the sides of the abdomen. Nothing is known as to the metamorphosis of these larvæ, and some examples of the type reach a size considerably greater than that of any Lycid beetle as yet discovered. The two species shown in the photographs are found together, beneath the bark of dead trees and under fallen timber in the jungle. The broader and more highly specialised of the two bears no resemblance, as far as I have been able to discover, to any other animal; but the narrower species, which in its younger stages differs very little from the ordinary type of Lycid larva, is not unlike a Millipede (*Orthomorpha sp.*) found together with it.

The fifth and three following photographs showed a pupa of the mantis *Hymenopus bicornis* seated on an inflorescence of *Melastoma polyanthum*. In its active pupal stage this insect bears so close a likeness to the flowers of the 'Rhododendron' that I have found it impossible to assign the exact limits of true vegetable tissue and animal counterfeit, even when holding in my hand an inflorescence in which one of these mantises was seated. The resemblance is brought about by the development of broad, petal-like expansions of the femora of the second and third pairs of legs, by the pink coloration of the insect, and by the extraordinary flower-like sheen of its integument. A broad bar of vivid green runs across the thorax of the pupa, dividing the animal visually into two perfectly distinct parts: a black spot is most conspicuous on the tip of its abdomen; and five brown lines mark the dorsal surface of the abdomen longitudinally. The mantis refuses to settle on any other part of the plant than the inflorescence. It sits among the flowers with its abdomen flexed backwards, so as to lie almost parallel to the thorax; and it sways its whole body from side to side. The movement attracts certain minute flies, which settle indiscriminately on the body of the insect (being then indistinguishable at the short distance from the black tip of the abdomen) and on the petals it simulates. The mantis takes no notice of these small flies, but seizes and devours larger Diptera, and probably other insects, that come within its reach. When the flowers among which it is seated commence to fade, the mantis droops its abdomen, thus bringing the brown lines upon the dorsal surface into view, and finally leaps to the ground. When separated from the inflorescence of *Melastoma polyanthum*, it resembles an orchid that has fallen from its stem. *Hymenopus bicornis* has a fairly wide distribution (from Sikkim to Sarawak), but it is rare in every locality where it occurs. A white variety of the pupa is also known.

The ninth photograph showed some Siamese of the State of Patalung clapping their hands to attract the edible cicada (*Dundubia intemerata*). In April the females of this insect are thus captured in considerable numbers for food, during the short interval between sunset and darkness. The cicada-catchers must clap their hands in unison and observe a definite rhythm. A fire is a usual, but not a necessary, adjunct to the performance.

The enormous elongation of the anterior region of the head of many Fulgorinæ (lantern flies) into a hollow nose-like organ has often puzzled entomologists, who have generally abandoned the old theory that this structure was luminescent. I was so fortunate as to observe its use as an organ of progression, or rather of sudden flight from danger. When the insect is disturbed, it presses the tip of its 'nose' against the tree-stem on which it is seated, at the same instant pushes its body violently away with its powerful legs, and so is projected for a considerable distance through the air, the 'nose' being flexible at one point, and also so elastic that it acts as a piece of whalebone would do under like circumstances.

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2. *Observations on Mimicry in South African Insects.* *By* Guy A. K. Marshall.

[Arranged and communicated by Edward B. Poulton, M.A., F.R.S., Fellow of Jesus College, Oxford, and Hope Professor of Zoology in the University.]

The following paper is an abstract of the results obtained by Mr. Guy A. K. Marshall in South Africa. When no locality is mentioned it is to be understood

that the observation was made at Salisbury, Mashonaland (5,000 feet). The observations here briefly recorded have added in a most important manner to our knowledge of the natural history (bionomics) of South African insects, a subject of which the foundations were laid by Roland Trimen. Groups of mimetic Lepidoptera captured on the same day as their models have been obtained both from Natal and Mashonaland (Salisbury), thus demonstrating more fully than has been done hitherto the fact that model and mimic fly at the same time as well as in the same place. The groups bring out the extraordinary power of Danaine butterflies in, so to speak, moulding the species of other sub-families into a superficial likeness to themselves. There are only four or five species of *Danainæ* in the region under consideration, and each one of them is the centre of a group of forms superficially similar, but remote in affinity. The abundant and widespread *Limnas chrysippus* was largely resembled both in Natal and Mashonaland. In experiments conducted upon insect-eating animals, this butterfly appeared to be less unpalatable than the *Acræa* (*A. encedon*) which resembles it. The explanation may be found in the far wider range of the Danaine model, which would render it familiar to enemies passing from an area in which the *Acræa* does not, to one in which it does exist.

In the case of two forms of *Euralia* (*E. mima* and *E. wahlbergi*) mimicking two very different species of *Amauris* (*A. echeria* and *A. dominicanus*) there is good reason to believe that a single species has become dimorphic. Photographs of four *mima* (two male, two female) and four *wahlbergi* (three male, one female) were shown, the whole set having been part of a company of twelve individuals going to rest together on a small clump of fern under a steep kraantz, Umbilo River, Malvern, near Durban, Natal (June 28, 1897). The two forms have also been taken *in coitu*, and have been found together freshly emerged from the pupa on the same tree. Intermediate varieties are also known. If specific identity be established, the case will constitute a new form of mimetic dimorphism in the Lepidoptera, similar to that of the Dipterous genus *Volucella.* All cases of dimorphism in mimetic Lepidoptera hitherto described are either sexual or confined to a single sex. In one sex, indeed, a mimetic species may be polymorphic, as in the female of *Papilio cenea* or *Hypolimnas misippus.*

In the case of the distasteful sub-family *Acræinæ*, the two very different species *A. natalica* and *A. anemosa* were shown captured at Salisbury on the same day. Although entirely different in detail, the pattern of the two species is broadly the same, and during flight would probably appear to be identical. Another even more striking example of Müllerian or synaposematic resemblance was afforded by a set of eighteen specimens belonging to five species of small Acræas captured on the same day (December 31, 1898) in the same locality. The whole group presented a wonderfully uniform appearance in size, shape, colour, and the general distribution of markings.

An example of a Hesperid (*Baoris netopha*) mimic of an *Acræa* (*A. doubledayi*), the two captured on the same day, added another to the rare instances of mimicry in this family. The resemblance is only seen in the attitude of rest, and is confined to the undersides of the wings.

The aberrant Lycænid (*Alæna amazoula*) has a general Acræine aspect, and is very unlike the well-known appearance of its true family. It is probably distasteful, and is resembled with tolerable closeness, especially upon the undersides of the wings, by a day-flying Geometrid moth (*Petovia dichroaria*). They were captured together at Malvern, near Durban, on September 26, 1897.

A most interesting series of injured specimens of butterflies showed the probable attacks of birds or lizards, observations in the field affording strong support to this interpretation. Members of the specially protected conspicuous groups were, as Fritz Müller showed in the case of South America, also subject to attack. Comparatively few of the injuries were inflicted at the junction of the fore and hind wings, or indeed anywhere except at the apex of the fore wing, or, more commonly still, at the anal angle of the hind wing. In many cases the injury was symmetrical, indicating that a piece had been bitten out of both right and left wings during the usual attitude of rest, or as they came together momentarily in flight. The two points of special attack are commonly rendered con-

spicuous by special marks, and, in the case of the hind wing, structures such as 'tails,' 'eye-spots,' &c. In the *Lycænidæ*, where the 'tails' are rendered still further prominent by movement, many specimens were captured with these parts bitten out from one or both of the wings.

Large additions were also made to our knowledge of mimicry and warning colours in Coleoptera. In the Carabid genus *Anthia*, a probable warning character common to different species consisted in a large white patch, placed in some species on the sides of the thorax, in others on the anterior surface of the elytra. The general effect was the same, but the anatomical relations entirely alien. The characteristic banded pattern of the *Cantharidæ* was shown to be resembled by beetles of widely different groups, the spotted pattern of the *Coccinellidæ* by an Hemipterous insect (*Steganocerus multipunctatus*), while the appearance of many S. African species of *Lycidæ*, light-brown anteriorly and black posteriorly, was reproduced in beetles of many groups, many species of Hymenoptera, an Hemipteron, two moths from remote sections of the order, and a fly. In the vast majority of these cases of likeness to and among Coleoptera, it is probable that the resemblance is Müllerian (synaposematic) rather than Batesian (pseudosematic). The interpretation of the remarkable likeness borne by a species of Longicorn (*Phantasia gigantea*) for certain *Curculionidæ* is more uncertain, although it is clear that some general principle is at work, inasmuch as resemblances between other species of the same groups are well known in many parts of the world. An interesting group of superficially similar insects from three different orders consisted of a Bracon, a Reduviid bug, and a Longicorn beetle.

Evidence of the struggle for existence in Coleoptera was supplied by a group of five beetles taken from the crop of a Guinea-fowl (*Numida coronata*). The four species belonged to the Buprestids, Curculios, Longicorns, and Phytophaga. All the beetles had been swallowed whole and were almost uninjured, even as regards limbs and antennæ.

Among the other orders of Insecta the Hemiptera afforded a wonderful example of mimicry or common warning colours from Malvern, near Durban, the Reduviid bug *Phonoctonus nigro-fasciatus* bearing the most remarkable likeness to the somewhat smaller Lygæid *Dysdercus superstitiosus*. The mimetic resemblance of Diptera to Aculeate Hymenoptera was illustrated by many examples, model and mimic having been captured in the same place and within the same month. The most remarkable of these was a splendid new species of *Hyperechia*, closely resembling the black, reddish-brown banded, African species of *Xylocopa*, such as *X. flavo-rufa*. Instances of common warning (synaposematic) colours in Hymenoptera were also illustrated by a group of three species with a general resemblance to each other: the Aculeata being represented by a species of *Myzine* and one of *Ceropales*, the Terebrantia by a species of *Ichneumon*. All were captured at Salisbury in January 1899.

The whole of the material here briefly described may be seen in the Hope Department of Zoology, Oxford University Museum.

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3. *Observations on Mimicry in Bornean Insects.* *By* R. Shelford, *B.A., Curator of the Sarawak Museum.*

[Arranged and communicated by Edward B. Poulton, M.A., F.R.S., Fellow of Jesus College, Oxford, and Hope Professor of Zoology in the University.]

The following paper is an abstract of results obtained by Mr. R. Shelford, B.A., Curator of the Sarawak Museum, British North Borneo. The vast majority of his observations were made at or near Kuching, the capital of Sarawak; a few, however, in Singapore. When no locality is mentioned, Sarawak is to be understood. The observations form a very important addition to our knowledge of mimicry in Malayan insects, especially the Coleoptera.

Among Lepidoptera an *Elymnias*, believed to be a new species from Mount Penrissen, is a tolerable mimic of the well-known *Euplœa, Tronga crameri*. Among the Chalcosid moths, three species of *Isbarta* mimicked two of *Euplœa* and

one of *Pierinæ* (*Delias cathara*). The latter is of considerable interest, inasmuch as the Pierine model appears to be excessively rare. There can be little doubt, however, as to the true relationship, for another species of the same genus, *I. pandemia*, is a magnificent mimic of another species of *Delias* (*D. pandemia*), both coming from Mount Kina Balu in North Borneo.

In the Neuroptera the Mantispides are shown to be mimics, a splendid new species (*M. simulatrix*, McLachlan) resembling a common Bracon flying with it on Mount Matang, near Kuching, while a small species from Singapore (*M.? cora*) exactly mimicked an ichneumon flying with it.

It is in the Bornean Coleoptera, and especially the Longicornia, that by far the largest additions to the subject of mimicry have been made. Many Longicorn species, chiefly of the genus *Oberea*, were excellent mimics of the *Braconidæ*, and perhaps other Hymenoptera. The long narrow form of the beetle resembled the *Bracon* at rest with wings folded. As seen from the side, certain species of *Oberea*, notwithstanding their uniform diameter, were apparently 'waisted' like a Hymenopterous insect, the effect being due to a conspicuous white patch on the side of the anterior abdominal segments. The part of the body thus covered is obliterated, while the outline of the patch is such that the uncovered, and therefore conspicuous, part of the body conforms to the shape of a slender 'waist,' from the posterior end of which the abdomen gradually swells. The effect in one species is as perfect as if an artist had deliberately painted the profile of a Hymenopterous abdomen upon that of a beetle. Among other examples of the same form of mimicry was a magnificent Cerambycid from Mount Penrissen (*Nothopeus* or n. gen., n. sp.), a beautiful mimic of the abundant wasp, *Salius sericosoma*, which flew with it. The common Dammar Bee (*Trigona apicalis*), which does not sting, but is formidable because of its bite, is the centre of a group of three species with the most remote affinities. Not only is there a Longicorn, *Epania singaporensis*, but a *Bracon* and a Reduviid bug. The mimicry is probably Müllerian in most, if not all, of the species of this group.

Another important set of Longicorns, species of *Entelopes*, *Tropimetopa*, *Chreonoma*, and *Astathes*, were extremely perfect mimics of Phytophaga (*Galerucidæ*). In one large group both models and mimics were reddish-brown, in another iridescent blue-black, in a third anteriorly blue-black, posteriorly reddish-brown. Another species of *Entelopes* (*E. glauca*) resembled a common Coccinellid (*Caria dilatata*), a Cassid also falling into the group.

The *Lycidæ* were models for Longicorns and other insects in Borneo no less than in South Africa. Species belonging to the Longicorn genera *Erythrus*, *Ephies*, *Xyaste*, and *Eurycephalus* mimicked Lycids with remarkable accuracy. In the last-named genus one species, *E. lundi*, was a mimic, while another closely related (*E. cardinalis*) exhibited a warning coloration of the most startling character, an indication that the genus is distasteful and the mimicry Müllerian. In addition to these, the Lycids were mimicked by a Clerid beetle, by numerous Hemiptera and a Zygænid moth, the latter from Singapore.

The resemblance of certain Longicorns to the Rhynchophora was far more evident than in South Africa, for not only was there a mimic (*Trachystola granulata*) of a Curculionid (*Sipalus granulatus*), but there were species belonging to no less than four genera mimetic of the *Brenthidæ*. These latter mimics hold their long antennæ extended forwards side by side, the tips only, or in some species the anterior halves, diverging. Thus the rostrum of the Brenthid, together with its usually short antennæ, are represented by the long antennæ of the Longicorn. The *Anthribidæ* were mimicked by Longicorns of the genera *Ereis* and *Cacia*.

A feature of both Rhynchophorous models and their mimics, and one very unusual in mimicry, is the inconspicuous mottled colouring and the absence of strongly contrasted tints.

A very interesting Longicorn mimic of an Endomychid beetle (*Spathomeles* sp. near *turritus*) was a rare species of *Zelota* as yet undescribed.. The curved spine on the elytron of the model was represented by a brush of hairs on that of its mimic. Experiments indicated that the *Endomychidæ* as a group were distasteful, and large synaposematic sets of purplish black, yellow or orange

spotted species were found near Kuching together with several species of *Erotylidæ* and a Pentatomid bug with the same general appearance. Another group of dark Endomychids was rendered conspicuous by numerous spines (*Amphisternus*).

Two groups of Longicorns were mimicked by other Longicorns belonging to entirely different sections. The iridescent green *Cerambycidæ* of the genus *Chloridolum* were closely resembled by two *Lamiidæ* (*Saperdinæ*? genus, and *Chlorisanis viridis*) and by the Cerambycid genera *Xystrocera, Psalanta,* and *Leptura.* Many genera and species of the banded Cerambycid *Clytinæ* were very closely mimicked by *Lamiidæ* and other *Cerambycidæ.* This last case is of peculiar interest, inasmuch as the *Clytinæ* are themselves perhaps the most conspicuous mimics of Hymenoptera to be found in the whole of the Longicornia. All over the world their numerous species commonly present a black yellow-banded appearance bearing a general resemblance to wasps, while mimicry of *Mutillidæ, Cicindelidæ,* and, in the allied *Tillomorphinæ,* of ants is also found. When, therefore, we also find that this group itself furnishes numerous models to other Longicorns, we are driven to conclude that it is in some way specially defended, and that its resemblance to Hymenoptera is Müllerian rather than Batesian.

The mimetic resemblance to the aggressive and active *Cicindelidæ* was very marked, examples being afforded not only by Longicorn beetles of the genera *Sclethrus* and *Collyrodes,* but also by a Dipterous insect found flying together with its model (*Collyris emarginata*) on Mount Seramba, December 1898. This is the first example of the mimetic resemblance of a fly to a tiger beetle. The remarkable Locustid mimic *Condylodera tricondyloides* (or a closely allied species) described by Professor Westwood from Java was also rediscovered in Borneo, and its habits for the first time observed.

Indirect evidence that the mimicry of *Cleridæ* is Müllerian rather than Batesian is similar to that which pointed to the same conclusion in the Longicorn *Clytinæ.* One Bornean species of a Clerid genus (*Thanasimus*) resembled a Mutillid, another (genus near *Tenerus*) a Lycid, while a third, a species of *Lemidia,* was mimicked by the Longicorn *Daphisia pulchella.*

Among the Diptera a splendid black *Hyperechia* (*H. fera*) was a beautiful mimic of the abundant *Xylocopa latipes,* another example of parallelism with South African bionomics. An allied species, *Laphria* sp. near *Terminalis,* was an excellent mimic of *Salius aurosericeus.* Dipterous mimics of Hymenoptera are extremely abundant in Borneo: remarkable among them was a species which mimicked an ichneumon of the genus *Mesosternus.* The short antennæ of the fly in no way resembled the very long black and white ones of the ichneumon. The fly, however, held up its black and white legs, applying their bases to its head and moving them so that they closely resembled the antennæ of the Hymenopterous insect in movement as well as in colouring and proportions. Another species of fly possessed true antennæ which were remarkably long for this order, and thus closely resembled those of an ichneumon.

With few exceptions, the whole of the material here briefly described may be seen in the Hope Department of Zoology, Oxford University Museum.

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4. *Note on an Experiment supporting the General Principle of 'Müllerian' Mimicry. By* Professor C. Lloyd Morgan, *F.R.S.*

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5. *Illustrations of Mimicry and Protective Resemblance. By* Mark L. Sykes.

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6. *The Colour Physiology of* Hippolyte varians *By* F. W. Gamble *and* F. W. Keeble.

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7. *The Locust Plague and its Suppression.* *By* Æ. Munro, *M.D.*

Locusts have devastated the greater part of the habitable world, and during the last ten years have done great damage in the southern republics of South America, in North and South Africa, in India, &c.—countries widely separated from each other—and they have caused great loss of human and animal life in large areas in Africa belonging to Britain. The importance of the subject is therefore considerable. But the difficulties which hitherto have been connected with the plague seemed excessive and insuperable barriers in dealing with it effectually.

To illustrate the remarks in this paper I select the four following typical and well-known species of the insect, namely, 1, the *Caloptenus spretus,* or Rocky Mountain locust; 2, the *Stauronotus criatus,* or Cyprian locust; 3, the *Schistocerca paranensis*; and 4, the *Acridium peregrinum,* or Old World locust, in order to emphasise in a more pointed way certain aspects or characteristics of the insect which I think it well to put prominently forward in attempting to bring this plague under review, and asking favourable attention as to the best means to check it and alleviate the distress.

a. Our increased and gradually accumulating knowledge of the habits of the insects is derived mainly while the insects come to and sojourn in their temporary homes, for we do not yet know them in their permanent or true homes. The one and only success in combating the plague by human means in the whole history of the world was due to the putting in force the simple observation that the young (or the old) locusts cannot adhere to smooth surfaces, such as glass, owing to the fact which is now made abundantly clear, namely, that, unlike flies, the processes or claws on the feet of their front and middle pair of legs are too short and weak to enable them to do this.

b. The general and characteristic features of the locust run through all the species alike. This fact has been greatly lost sight of or minimised, and the differentiations which help to mark off one species from another have been magnified into an unjustifiable and unnecessary importance. The instincts and the structure of all the varieties are very nearly alike, although one species may not be so large or have different markings as compared with another.

c. The *direction* which the 'army' assumes when the larvæ at a certain period set out for and continue on their 'march' is a most important matter to settle and be certain about, as this is the most destructive period in the life of the insect. They then devour everything that comes in their way. Not so with the flight of flying locusts, which only levy toll here and there as they pass or sojourn. The 'army on the march' usually pursue a straight given course, irrespective of all obstacles and dangers (natural or artificial) that may be in their way, minus any with *smooth* surfaces owing to the reason above stated. Now the course or direction of the 'march' will be found (though further observation is requisite to confirm the truth fully) to be always in a given direction in certain countries. Thus in the Argentine and South Africa they travel southwards, in Algeria northwards, in the United States eastwards, and so on. It may not be true south, or true north, or true east in the respective instances mentioned, but it will be respectively *towards* the south, north, or east, as the case may be. The important thing to bear in mind is that they all march in one general direction as a body at the same time, and without any leader; while so far as suitability and abundance of food are concerned to satisfy all their instincts an exactly opposite or other direction would be far better. The 'Screen and Trap' or 'Cypriote' system was based on the supposition that the insects march in a given specific direction. It has been owing to this fact that the power of the plague was broken in the course of *one year* (1883) in Cyprus, although it baffled all efforts to check it for centuries before. Since the suppression of the plague, and no doubt very much on account of it, Cyprus has entered on a new era of prosperity.

Outline of the Means for Checking or Suppressing the Plague.

There is a sense in which a plague or pest such as that of locusts may be regarded as the increase over the natural checks with regard to the normal number.

When this gain takes place it is now almost universally admitted that human measures ought to be resorted to with the view of aiding the natural agencies, so that the insects may be reduced in number to a point that is safe or free from danger.

I. *The Natural Agencies for Checking the Plague.*

Destruction by (1) the wind; (2) birds; (3) reptiles, lizards, toads; (4) mammals and fish; (5) wasps; (6) disease:—(*a*) internal larvæ from the Tachino fly, (*b*) Mylabris parasite, (*c*) Mermis parasite, (*d*) Cynomia pictifacies parasite, (*e*) Empusa grylli parasite, (*f*) various others, such as mites; (7) eggs destroyed by insects, animals, weather, water.

II. *Artificial and Mechanical Means for Checking the Plague.*

1. Ingenuity or finessing. 2. Destruction of the eggs by—(*a*) Machines, ploughs, harrows; (*b*) eating by pigs; (*c*) tramping the ground; (*d*) irrigation; (*e*) judicious use of chemicals; (*f*) collecting the eggs. 3. destruction of hoppers by—(*a*) maiming, (*b*) crushing, (*c*) tramping with stock, (*d*) diverting, (*e*) catching and bagging, (*f*) trapping, (*g*) burning, (*h*) use of chemicals, (*i*) inoculation of fungi. 4. Destruction of the winged locusts by—(*a*) diverting a flock or flight, (*b*) shooting them on the wing, (*c*) maiming, (*d*) chemicals, (*e*) tramping, (*f*) crushing, (*g*) burning, (*h*) catching and bagging, (*i*) inoculation of the flying locust with a fungus.

Section E.—GEOGRAPHY.

President of the Section—Sir George S. Robertson, K.C.S.I.

THURSDAY, SEPTEMBER 6.

The President delivered the following Address:—

When the British Association for the Advancement of Science honoured me with an invitation to preside over this Section, I accepted the distinction, thoughtfully and with sincere gratification. The selection as your President at Bradford, this great and interesting centre of commercial energy, of a student of political movements who was also deeply interested in the science of geography, seemed to point suggestively to a particular branch of our subject as appropriate for an opening address. This consideration, and, to my thinking, the fitness of the occasion, led me to believe that the British Empire itself was a very proper subject for such reflections as could be compressed within the limits of an inaugural Presidential Address. Many of my predecessors have eloquently and wisely dealt with various topics of admitted geographical rectitude—with geography in its more strictly scientific study, with its nature and its purview, with its recent progress, and with the all-important question of how it could be best taught methodically, and how most profitably it might be studied. In dealing with the important practical application of our science to the facts of national life—Political geography—I feel that perhaps a word of explanation is necessary. Pure geography, with its placid aloofness and its far-stretching outlook, combined sometimes with a too rigid devotion to the facts and conclusions of strict geographical research, is apt to incline many scientific minds to an admirable quiet-eyed cosmopolitanism—the cosmopolitanism of the cloistered college or the lecture theatre. It perhaps also at times has a tendency to create in purely academic students a feeling of half disdain or of amicable irritability against those who love the science for its political and social suggestiveness and elucidations. Thus there is a possible danger that geographers of high intellectual calibre, with enthusiasms entirely scholarly, may come to underrate nationality and to look upon the world and mankind as the units, and upon people and confederacies and amalgamations merely as specific instances of the general type. We know that geography is often looked upon as the science of foreign countries more especially. Such mental confusion is undoubtedly less common than it was, yet it still influences, unconsciously, the minds of many people. It is well not to forget this curious fact, and to point out, as if it required emphasising, that there is nothing foreign to geographical thought in the association of geography and patriotism, and that the home country is worthy of careful study, particularly when, as with us, our home country is not Yorkshire, nor England, nor the United Kingdom, but the whole British Empire. That is my justification and my apology for taking Political Geography and the

British Empire as my subject, if justification and apology seem to any one to be necessary. To the generous hearts of our distinguished foreign visitors who honour us quite as much as they delight us by their presence, I am sure of my appeal. Every true man loves his own country the best in the world. That beautifying love of country does not require him to be ignorant of or to hate other countries. The community of the civilised nations, no longer to be described as Christendom even, for Japan has been received into it, is a mighty fact in geography no less than in politics. To love mankind one must begin by loving individuals; before attaining to true cosmopolitanism one must first be patriotic.

Now, besides dealing with the topography of the globe, geography considers also the collective distribution of all animal, vegetable, and mineral productions which are found upon its surface. The aspect of the science which deals with man's environment, and with those influences which mould his national character and compel his social as well as his political organisation, is profoundly interesting intrinsically and of enormous practical usefulness when rightly applied. Given the minute topography of a country, a complete description of its surface features, its rivers, mountains, plains, and boundaries, a full account of its vegetable and mineral resources, a knowledge of its climatic variations, we have at once disclosed to us the scene where we may study with something like clearness man's procession through the ages. Many of the secrets of human action in the past are explained by the land-forms of the globe, while existing social conditions and social organisations can often thereby be intelligently examined and understood. Persistent national characteristics are often easy to explain from such considerations. For instance, the doggedness of the Dutch river-population, caused very greatly by a perpetual struggle against the sea, or the commercial carrier-instinct of the Norwegians, those northern folk born in a country which is all sea-coast of countless indentations. Having few products to barter, the Norwegians hire themselves to transport the merchandise of other peoples. We British also were obviously predestined to isolation and insularity, when perhaps in the human period the Thames ceased to be a tributary of the Rhine. Our Irish fellow-countrymen were similarly fated for all time to lead a separate, special, and national life apart from our own, when at a still earlier period, geologically, the Irish Channel was formed.

Such large-scale facts are not to be overlooked; there are others, however, of varying degrees of prominence. Some merely require to be interpreted thoughtfully, while others, after diligent study, may still remain dubious and matter for speculation. Geography is the true basis of historical investigation and the elucidation of contemporary movements. At the present time great social and political changes are occurring throughout the world—in Europe, Asia, Africa, and America, and in the islands of the great seas. These changes are absolutely dependent upon the physical peculiarities of the different lands acting upon generations of men during a prolonged period of time. As a consequence of certain soils, geographical characteristics, and climates, we notice how harsh surroundings have disciplined some races to hardiness and strenuous industry, accompanied by keen commercial activity, which is itself both a result of increasing population and the cause of still greater overcrowding. Then we see other people at first sight more happily circumstanced. With them the struggle to live is less ferocious, their food is found with little toil. But we perceive that the outcome of generations of Nature's favouritism has been to leave them less forceful and less ingenious in the never-ending warfare of existence. By comparison they grow feeble of defence against the hungrier nations, ravenous for provender. Man for ever preys upon his own kind, and an easy life in bland surroundings induces a flabbiness which is powerless against the iron training of harsh latitudes, or against the fierce energy and the virile strength produced by hereditary wrestling with unkindly ground.

The discovery of America and Vasco da Gama's voyage round the Cape originated movements and brought into play those subtle influences of foreign lands upon alien sojourners, and through them upon their distant kindred, which alter the course of history and modify national manners and perhaps national characteristics also. The colonisation of territories in the temperate zone by European

Governments, separated by vast ocean-spaces from their offshoots, has given origin to new and distinct nations different from the parent stock in modes of thought and in ways of life, a result due mainly, no doubt, to local physical conditions, but in part also, if only in part, to detachment, to complete and actual severance from the mother country. This brings us to that most interesting and important topic, geographically speaking, of Distance, an aspect of our science which is of the utmost concern to traders and to statesmen; indeed, an eminent German geographer defines geography as the Science of Distances. To this subject of Distance I wish in particular to direct your attention, and especially to its bearings upon the British Empire.

The British Empire is equal in size to four Europes, while its population approximates four hundred millions. Although that may seem a somewhat grandiloquent method of description, it is a fairly accurate statement of fact. Still more interesting to us is another truth—that outside of these islands we have some ten millions of white-skinned English-speaking fellow-subjects. These islands are scarcely more than one-hundredth part of the whole Empire, although we count as four-fifths of its white population; of the total number of the Queen's subjects we are, however, no more than a tenth.

British Empire is somewhat of a misnomer, just as the North American and Australian Colonies were never colonies at all in the classical sense of the word. For the colonies are not independent of the mother country. An empire again really means a number of subject peoples brought together, and at first held together, by force. India is an empire for instance. Some new title or phrase would have to be invented to describe accurately all the possessions of the British Crown from the Government of India through all possible grades of more or less direct control until we come to some colony with representative institutions, and thence to the great commonwealths with responsible legislators and responsible cabinets. Happily, however, there is no need now for any novel designation. The style *British Empire* has become in time of stress a rallying cry for all the Queen's subjects, and the term has been sanctified by the noble eager devotion shown to her Majesty, both as a beloved and venerated constitutional sovereign, and as the common bond of unity between those great self-governing daughter-nations which we in the past were accustomed to speak of as 'our colonies.' Consequently *British Empire* has henceforward a clearly defined, a distinct, a national significance, just as Imperialism has a special and peculiar meaning to all of us. We understand by *British Empire* and by *British Imperialism* a confederacy of many lands under the rule of her Britannic Majesty. This confederacy is dominated by white peoples—Anglo-Saxons, Celts, French-Canadians, and others—knit together in most instances by the ties of blood relationship, but with equal if not greater closeness by common interests, an identical civilisation, and a love of liberty, in addition to that dignified but enthusiastic acceptance, already referred to, of the constitutional sovereignty of the same Queen. We may hope that generous democratic expansiveness and social assimilation will also in time detain willingly within the limits of this British confederacy of white peoples those other Christians and distant kinsfolk of ours in South Africa who are at present so bitterly antagonistic.

Ruled and controlled under liberal ideals by the centre of authority there are, in addition, the great subject territories whose non-Christian population are less advanced in moral and material progress. They exhibit indeed every degree of backwardness, from the barbarism of the savagest tribesman to the intellectual but archaic civilisation of ancient Asiatic nationalities.

Concerning the British Empire, and comparing it with other empires, ancient, recent, or now existing, its two most remarkable features are its prodigious and long-continued growth and the persistency of its power. It cannot to all seeming grow much larger, from lack of expansive possibility. But it is unprofitable to predict. Every step which has been taken in the way of extension, particularly of late years, has been against the wishes and in almost passionate opposition to the views of large sections of the people. Yet the process of enlargement has gone on continually, being often in actual despite of a Government, whose members find themselves powerless to prevent absorptions and concretions which

they would gladly avoid. Objections to this perpetual growth of empire in territory, and to the resulting responsibility which we not altogether willingly accept, are unanswerable theoretically. The too heavy and continually increasing strain upon our military resources every one can appreciate. The limit in power of the strongest navy in the world is at least as obvious as the vital necessity that our Navy be largely and ungrudgingly strengthened. Naturally the cry of cautious patriotic men is the same now that it has always been—'Consolidate before you step farther.' In India, owing to conscientious and strenuous opposition to every suggestion of expansion and to the almost violent form which that opposition often took, our progress has been on the whole slow and comparatively safe. We have (I, of course, avoid all allusion to very recent policy) as a rule consolidated, strengthened ourselves, and made our ground sure before another advance. But there is a general impression that in other parts of the world we have been hastily and unfortunately acquisitive, whether we could help it or not; that the new provinces, districts, and protectorates are some of them weak to fluidity; that the great and unprecedented growth of the Empire has led to a stretching and thinning of its holding links which are overstrained by the weight of unwieldy extension and far beyond the help of a protecting hand. I hope to be able to show that in some important respects this suspicion is not altogether true; that science, human ingenuity, and racial energy have given us some compensations, and that it is not paradoxical nor incorrect to say that our recent enormous growth of empire has been everywhere accompanied by a remarkable shrinkage of distances—by quicker and closer intercommunication of all its parts one with another and with the heart centre. In short, the British Empire, in spite of its seemingly reckless outspread, its sometimes cloudy boundaries, its almost vague and apparently meaningless growth, is at the present day more braced together, more manageable, and more vigorous as a complete organisation than it was sixty years ago. The difference between its actual extent in the last year of the century and its size at the date of the Queen's accession can be estimated by a glance at a remarkable series of maps published in the 'Statesman's Year-book for 1897,' while since 1897, and at this instant as we all know well, its mighty bulk is being still further increased.

The world as a whole has strangely contracted owing to a bewildering increase in lines of communication, to our more detailed geographical knowledge, to the formation of new harbours, the extension of railways, the increased speed and the increased number of steamships, and the greatly augmented carrying power of great sailing vessels built of steel. Then, hardly second in importance to these influences are the great land lines and the sea-cables, the postal improvements, the telephones and, perhaps we may soon add, the proved commercial utility of wireless telegraphy. This universal time-diminution in verbal and personal contact has brought the colonies, our dependencies, protectorates, and our dependencies of dependencies, closer to each other and all of them nearer still to us. Measured by *time-distance*, which is the controller of the merchant and the cabinet minister just as much as of the soldier, the world has indeed wonderfully contracted, and with this lessening the dominions of the Queen have been rapidly consolidating. Nor is this powerful influence by any means exhausted. In the near future we may anticipate equally remarkable improvements of a like kind, especially in railways, telegraph lines and deep-sea cables, and in other scientific discoveries for transmitting man's messages through water, in the air, or perhaps by the vibrations of the earth. For us particularly, railway schemes of expansion must be mainly relied upon to open up and to connect distant parts of the Empire. Our true and only trustworthy road of intercommunication between the heart of the Empire and its limits must always be the sea. For general trade purposes, such as the convenience of business travellers, all continental lines and all the great projected railways will be helpful, whatever nation controls them; but our certain security is the sea, the sea which protects us, which has taught us to be an Imperial people. If we ever forget that, there may be a calamitous awakening. We must not be persuaded to build—or at any rate to place reliance upon—land roads or railways through regions inhabited by tribes and peoples over whom we

have not complete military as well as political control. Persian, Arabian, North African railway projects are happily rarely heard of now. As national enterprises they never were and never could be practicable, or otherwise than dangerous mistakes. We are a world-power solely because of our worship and because of our command of the sea. In the future also we shall remain a world-power only so long as we hold command of the sea in the fullest sense of the term, not merely by the force and efficiency of the fighting navy, but by the excellence and the perfecting of our mercantile marine, by increasing its magnitude, carrying power, and speed, and by anxiously attending to its recruitment by British sailors. We must not attempt to overtax our resources to guard railway lines through foreign semi-civilised or savage countries by exported or local armies. A heavy land responsibility lies upon us already. Under a little more we might be easily overweighted and crushed down. We must concentrate all our surplus energies upon our sea communications. Therefore the railway lines which I spoke of as helping to consolidate the Empire in the near future are those only which are projected or are being built in the various colonies and dependencies, lines to distribute and collect, to connect provinces, and feed harbours. The mighty Canadian Pacific Railway is unique in the Empire. It not only complies with all these requirements, but in addition it provides to Australia and the Eastern dependencies an alternative road, convenient and safe. As I said before, all railways, wherever built, will probably help us directly or indirectly in the long run, provided we are never committed to the protection of any one of them outside of our own boundaries.

And what has been said about railways applies, with obvious modifications, to telegraph lines and to maritime cables. The more general the extension of these, and the more numerous they become, the greater benefit will there be to this country in its double capacity as the greatest trader and the greatest carrier of merchandise in the world; while the actual equivalent to a diminution of time-distance in travelling is to be found in the instantaneous verbal message which can be despatched to the most distant point of the Empire. But we ought certainly to join all the shores of the Queen's dominions by sea-cables completely controlled by British authority. To rely upon connection between our own cables through telegraph systems stretching across foreign countries, however friendly, or to permit the ends of these sentient nerves of the Empire to emerge upon shores which might possibly become an enemy's country, is dangerous to the point of recklessness, that parent of disaster. As a melancholy instance of my meaning it is only necessary for us to remember the Pekin catastrophe—how we suffered from those dreadful intervals of dead silence, when we could not even communicate directly with our own naval officers at Taku, or with any one beyond Shanghai, although we have in our possession a place of arms at Wei-hai-Wei upon the Gulf of Pechili. It is obvious that we ought to have an all-British cable for pure strategic reasons as far as Wei-hai-Wei, our permanent military outpost on the mainland.

Now to give some suggestion of the increased facilities for carrying merchandise, for conveying passengers quickly about the world, and for the sending of messages to all parts of the earth, a few, a very few, salient facts may be quoted about ships—sailing ships and steam vessels—and about telegraphs and cables.

In 1870 there were no more than ten British sailing ships which exceeded or reached two thousand tons burden. In 1892 the yards on the Clyde alone launched forty-six steel sailing ships which averaged two thousand tons each. In 1895 the number of large steel sailing ships being built in the United Kingdom was down to twenty-three, and, speaking generally, it is inevitable that sailing vessels must give way to ocean steamships for most kinds of cargo—cattle, coals, wool, grain, oil, and everything else.

Now let us turn to the results in shortening journeys accomplished by the progress made in the construction and in the driving machinery of steamships within the last forty years, which has especially been fruitful in such improvements.

During this century the six months' voyage round the Cape to India became a forty and then a thirty days' journey by what was known as the overland route for mails and passengers through Egypt. By degrees it had become shorter still by the railway extensions on the Continent and by the unbroken steamship passage through the Suez Canal, until now the mails and hurrying travellers may reach London in twelve or fourteen days after leaving Bombay; and the great liners of the P. & O. Company can arrive in the Thames eight days later. This famous corporation, after her Majesty had been reigning nearly ten years, possessed only fourteen ships, with an aggregate of 14,600 tons. Now it owns a princely fleet of fifty-three ocean steamers, with a total capacity of 142,320 tons. Practically the voyage to India in her Majesty's reign has been diminished by one-half at least.

Also since the Queen's accession the passage between the British Isles and the Commonwealth of Australia has grown shorter, from the ninety days taken by the sailing clippers to the fifty-three days occupied by Brunel's *Great Britain*. At the present time it lasts from thirty to thirty-five days by the Suez Canal route, while it has been finished in as little as twenty-eight days. Australia is consequently only half as far away, in time, as it was; while, if the Suez Canal were closed for any reason, we have at our disposal, in addition to the Cape route with its quick steamers, which is linked to us by the Pacific Ocean road, the splendid service of that Empire-consolidator, the Canadian Pacific Railway.

The important part played by the Suez Canal in this connection will be discussed a little later. Now I am merely indicating by a few well-known facts the diminution of distance by the improvements which have been made in the ships themselves and in their propelling machines.

Across the Atlantic the rapidity of travelling and the general average speed of all cargo steamers have increased remarkably. Very interesting statistics on this point were given to the British Association for the Advancement of Science last year, at Dover, by Sir William White in the Presidential Address of Section G. We may say, without repeating details, that during the last half of the nineteenth century the breadth of the Atlantic has practically been diminished one-half.

In 1857 the Union Company contracted to carry mails in thirty-seven days to the Cape. Now the contract time is nineteen days. This again diminishes the distance by one-half. As an instance of the remarkable change which has been made in steamships within forty years, it may be mentioned that the first *Norman* of the Union Company took forty-two days to reach the Cape, while the present *Norman* has covered the journey in fourteen days twenty-one hours. I need not specify particularly the equivalent acceleration of speed upon other great steamship lines. All our sea distances have been shortened 50 to 60 per cent. in an identical way.

It is not too bold to predict that the Atlantic, from Queenstown to New York, will, before long, be steamed in less than four days. The question has now resolved itself simply into this—will it pay shipowners to burn so much coal as to ensure these rushing journeys before a cheaper substitute for coal is found? We know that a torpedo-destroyer has been driven through the water at the rate of forty-three miles an hour by the use of the turbo-motor instead of reciprocating engines. Consequently an enormous increase in the present speed of the great Atlantic liners is certain if the new system can be applied to large vessels. By such very swift steamers, and by the example they will set to all established and competing steamship companies, the journey to Canada and subsequently to all other parts of the Empire will be continually quickened, until predictions which would now sound extravagant will in a few years be simple everyday facts.

We must turn next to the subject of telegraphic communication, especially as it relates to the British Empire.

The mazes of land-lines and of sea and ocean cables are too numerous and intricate to be described in detail. Also the general effect of this means of bringing distant peoples together, and its transcendent importance for political, strategic, and trading purposes, need not be too much insisted upon in this place, so obvious must they be to every one. Yet, great as has been its power and advantage in all of those directions in the past, it is certain that still greater development and still greater service to the world will follow in the future even from existing systems,

not to speak of their certain and enormous possibilities of growth. In the celerity of the actual despatch of a message we need not ask for much improvement. Lightning speed will be probably sufficient for our go-ahead children of the twentieth century. But where we may expect and shall undoubtedly get increased success is in multiplied facilities for sending telegrams all over the earth, and in widening their usefulness and convenience to all ranks and sections of the community. To obtain these necessary advantages there are two requisites—first a great and general cheapening of tariffs and, as a certain consequence of such reduced charges, a duplication or even a quadrupling of many of the present cables to prevent blocking; and, secondly, an indefinite extension of both lines and cables everywhere. Progress in submarine telegraphy undoubtedly means a lessening in the price of service and a firmer control by the State, as an obvious corollary to the large help to the companies already given by the general taxpayer, quite as much as it means those scientific inventions and scientific discoveries which the coming years have in store for us. At the present time the charges are far too high, ridiculously so as regards India, and the use of the great cables is therefore very often beyond the power of the small capitalist and the trader of the middle sort. Yet certain and early news is of supreme importance to large numbers of both classes. Its absence hampers or stops business, while its price is too severe a tax upon average profits. This fact has led to the invention of ingenious and elaborate codes. They might possibly have been devised in any case; but there is no doubt that messages by code would be certainly expanded so as to prevent all possible ambiguity, if telegraphing to distant countries were not so costly. The spreading of land-lines and sea-cables about the earth has gone on rapidly since 1870; to the extent that those already completed would seem even to be in advance of their requirement, if that requirement were to be measured by their full employment. Nevertheless it is to be wished that new companies could be formed and new lines laid down to excite competition and thereby to cheapen rates; or else that our Government should step in and regulate charges over subsidised British lines. For the power of the great telegraph corporations, by reason of their monetary resources, enables them to overcome ordinary rivalry and to treat public opinion with indifference. A general cheapening of rates has constantly been followed by increased profits, earned by the resulting augmentation of traffic, but it needs an enterprising directorate to face the necessary initial expenditure, except under pressure. Boldness and foresight in finance are naturally less prominent features in the management of the great telegraph companies than contentment with a high rate of interest on invested capital. All their energy and watchfulness are employed to crush competition rather than to extend their activities indefinitely. Moreover, money-making is their business, not Imperial statesmanship. If it were a question of the added security or the close coupling-up of the Empire (which are probably synonymous) on the one hand and a loss of profit (however splendid the dividends might still remain) on the other, we know what would be the result of their deliberations.

Important as are the sea-cables for statesmen, for strategy, and for commerce, they are or will be equally important socially to keep up intimacy and swift intercourse between families half in Britain and half in India for instance, or between friends and relations in these Islands and in the great Colonies. They might be made to give the sensation almost of actual contact, of holding the hand of your friend, of speaking directly to his heart. It is this interchange of personal news and private wishes, quite as much as the profound political and commercial aspects of lightning communication with all parts of the Empire, which will bind the Empire in bonds stronger than steel, easy as affection, to hold it together with unassailable power. Consequently the health and strength of the Empire depend very greatly upon a cheapening of telegraph charges. Doubtless a time will come when all our main cables of the first importance will be in the hands of Government, when they will only touch upon British territory, and when they will be all adequately protected from an enemy. Those are truly Imperialistic and patriotic aspirations. But we must never forget the grand part in bringing together, within whispering distance as it were, the different parts of the world, and consequently of our world-wide Empire, which has been taken in the

past by such Napoleonic organisers as the late Sir John Pender. It is to him and to such men as he that we owe those splendid beginnings which by means of vital reflexes from the nerve-centre of the Empire have helped to fire our white fellow-subjects all over the globe with a loftier patriotism and with new, brave, and broader ideals of nationality.

It was coincident with the opening of the Suez Canal in 1869 that the liveliest interest began to be taken in sea-cables, and a master mind perceived their commercial possibilities. Before that time the success of the constructing companies had not been great. Sir John Pender then founded the famous Eastern Telegraph Company by the amalgamation of four existing lines, which had together laid down 8,500 miles of sea-cables, besides erecting land-lines also. A year later, in 1873, from three other companies he formed the Eastern Extension Australasia and China Telegraph Company, which jointly possessed 5,200 miles of submarine lines. From that date the extension of electric communication to all parts of the earth, over wild as well as over civilised countries, and beneath the salt water, has only been equalled by their average remunerativeness. Now there are 175,000 miles of submerged cables alone, of which this country owns no less than 113,000 miles. The history of some of these cables is full of interest, and might attract the delighted attention of the lover of picturesque romance no less than of the student of commercial geography. It also supplies suggestions and many facts, both to the physical geographer and to the student of seismic phenomena. Science has taught the companies to economise time, labour, and material in cable-laying operations, as well as how to improve the working instruments. Human ingenuity, business perception, and organising power have shown once more their startling possibilities when directed and controlled by cool, clear-eyed intelligence combined with general mental capacity.

It is only necessary to reaffirm, for the reasons already given, the national, the imperial, the commonwealth requirement for cheap telegraphy, and the profound necessity there is both strategically and politically for complete government control by purchase, guarantee, or other equitable means over main cables which connect Great Britain with her daughter states, her Indian empire, and her dependencies. Our communications with our own folk must be independent of private companies and completely independent of all foreign nations.

All the details which I have given are illustrative of man's successful energy and of his progressive ingenuity in enslaving the great forces of the earth to diminish distance, to shorten world-journeys, and to speed world-messages. Another human achievement, the piercing by Lesseps of the Suez isthmus, has had remarkable consequences. It had been talked of in England centuries ago. Christopher Marlowe makes Tamerlane brag :—

'And here, not far from Alexandria,
Whereas the Tyrrhene and the Red Sea meet,
Being distant less than full a hundred leagues,
I meant to cut a channel to them both
That men might quickly sail to India.'

The illustrious French engineer solved one great problem in 1869, only to originate others which are of profound importance to commercial geography—and to the British Empire most of all. The Suez Canal has brought India and the Australasian Commonwealth wonderfully near to our shores. It has greatly diminished many time-distances, but why has it not injured our Eastern trade? Also is there any danger or menace of danger to that trade? From the very beginnings of the great commerce, the Eastern trade has enriched every nation which obtained its chief share. It has been the seed of the bitterest animosities. It alienated Dutch and English, blood relations, co-religionists, co-reformers, into implacable resentment, and bitter has the retribution been. On the other hand it brought into temporary alliance such strange bedfellows as the Turks of the sixteenth century and the Venetians. At the present day what international jealousies and heartburnings has the same rivalry not fostered! For all the trading peoples know how vital is that traffic.

In the earliest days of commercial venturings the Eastern trade focussed at

Alexandria, afterwards at Constantinople and the Italian 'factory' stations of the Eastern Mediterranean. Barbarous upheavals in Central Asia interrupted the current at times, but only as temporary dams. Then came Vasco da Gama's voyage round the Cape and its sequels—the diversion of the rich merchandise of the Orient from the Italian ports and from the Eastern Mediterranean to the sea-coast cities of the Atlantic. Out of the relentless scramble of the Atlantic nations for this, the grandest of the trader's prizes, the English came out bloodily triumphant, and the British have remained the dominant shippers ever since. But when the Suez Canal was trenched through, a geographical reversal followed: the merchant's chief path may be said to have left the Cape circuit and to have regained the old line, with immensely added facilities, to debouch upon the Eastern Mediterranean. Why has it not affected us more profoundly? Are not geographical canons outraged by the great steamers passing by the French and Italian ports to find distributing centres in these islands? I think that theoretically it is so, even admitting that the foreign harbours are more difficult than ours. Practically only a few industries have suffered; the volume of our trade has increased greatly, and it still remains easily pre-eminent. One of the chief explanations I believe to be this: Geographical considerations were defeated, for the time at any rate, by the excellence of our banking system when the Suez Canal was opened. The wealth of the country, then as now, instead of being separated and divided into isolated patches, was accumulated in the hands of bankers and was readily and easily available for commercial enterprises. So the necessary steamers—huge, and of special line—were built at once by our companies and launched into the valuable Eastern trade before their rivals could begin to stir. This country had the invaluable help of its monetary facilities. Wealthy shipping corporations, once fully organised and successful, have great power, by reason of their reserves and resources, to hustle and to ride off the attacks of weaker and less experienced competitors. Supposing this great change had but just occurred—our advantages, though still distinct, would have been less remarkable. And in the future international trade jealousy will be keener and the competition even more severe. We must not forget that our geographical position is no longer in our favour for steamships plying from the East, and, as in the immediate past, we must throw away no chances, but seek to make up for that admitted defect by foresight, by education, by maintaining and constantly adding to our experience, and by defending and supporting that admirable system—our national banking system—which has carried us over seemingly insurmountable obstructions to brave trade triumphs.

The general considerations which I have named might lead to the inference that actual geographical disadvantages, in trade competition for instance, may sometimes be conquered by man's resourcefulness and energy. Within obvious limitations that is certainly true. At places, as we know, the borderland between geography and many of the natural sciences is often vague and confusedly interlaced. So perhaps also with mechanical and economic science our boundaries at certain spots overlap. Quick steamers, far-reaching telegraph lines, and the piercing of isthmuses by ship-canals may at the first glance appear outside the purview of the geographer. Yet from that particular aspect of geography which I have already spoken of as the Science of Distances we perceive how relevant they are, how worthy of study. Truly ours is a very catholic science, and we have seen how even the comparative value of national banking systems may help to explain seeming geographical inconsistencies, to reconcile facts with possibly unexpected results, and to show how the human element modifies, perhaps, the strictly logical conclusions of the geographer intent upon physical conditions alone. It is for the statesman and the philosopher to speculate upon the character and the permanency of such influences. Our success as an Empire will probably depend for its continuance upon a high level of national sagacity, watchfulness, and resource, to make up for certain disadvantages, as I think, of our geographical position since the cutting of the Suez Canal; and it will also depend upon the comprehensive and intelligent study of all branches of geography, not the least important of which to my view is the Science of Distances—the science of the merchant, the statesman, and the strategist.

The following Papers were read:—

1. *Attempts to improve the Teaching of Geography in Elementary Schools, especially in the West Riding.* By T. G. Rooper, *H.M.I.*

Reforms were begun through the Royal Geographical Society, whose collection of foreign maps was lent for exhibition in Bradford in the year 1887. The display of maps, models, and various devices for illustrating the instruction in geography in the elementary schools of Germany, France, and Sweden attracted special attention. Conferences were held in connection with the exhibition, one of which was attended by Dr. Scott Keltie, who made the collection.

One immediate result of these proceedings was the commencement of a series of local maps and models, a collection of which is exhibited. The conferences discovered the chief defects in the existing instruction: (1) Lessons in geography were not based on object teaching, nor on the observation of local features and scenery. (2) The art of 'reading' maps was not taught, nor was the construction of a map led up to by making plans of short walks and diagrams of the neighbourhood. (3) The study of political and commercial geography was not based upon the study of physical geography, neither were the details of geographical study connected as cause and effect. There was no attempt to present a country to the scholar as a connected whole, and the lessons consisted of lists of names and figures, at the most arranged in groups. Of such details many were wholly unsuited to the elementary stage.

The chief reforms consisted in the intelligent study of local geography through local maps and models, and in object lessons which explain the principles of physical geography. The reliefs and models led up to the art of reading maps and to the demand for better maps. Such lessons are an excellent introduction to reasoning, and prove how little there is that is purely arbitrary even in the sites of towns and villages in the neighbourhood, much less in the industries which are carried on in them.

The necessity for good wall-maps is now apparent, and correctly drawn details are demanded in place of vague and inaccurate sketches. Maps must interpret nature, and map reading is the converse of the process of studying home geography. In studying home geography the child begins with a natural feature such as a river or hill, and learns how to represent it on paper. On the other hand, in reading a wall-map the scholar begins with the symbols or representations of natural features which he has not seen, and arrives by means of them at the natural facts which such symbols represent. Hence the extreme importance of the right study of home geography and local models and reliefs. The symbols on the wall-map are vague and meaningless unless a content and significance are given them by previous practice in the building up of local plans and maps. The scholar has to be taught with care how to translate the symbols of the wall-map back into the forms of nature which they, however inadequately, represent. The difference between a good and a bad map is now apparent. As the scholar commences geography by the study of nature in a triple process, which consists of observation, description, and representation, so, if the wall-map be accurate enough, he can continue to draw inferences from it much as though he were actually observing the country by personal inspection.

The value of graphic work in teaching geography is insisted on. The mere copying and colouring maps of various parts of the world is rather an exercise in drawing than in geography. Each map should be drawn to serve some definite purpose. It should disentangle from a complex whole some particular part which analysis brings to light, and illustrate it with precision and simplicity. Further, the sketch-maps should proceed from simpler studies to more complex, and no map should be made of a country as a whole until the leading features have been dealt with separately, and thus the 'constructive' method of teaching geography is introduced.

The comparison of statistics of various kinds is made much more intelligible if the scholars learn to express their statistics by the use of square-ruled paper.

Abstract numbers are thus converted into concrete space forms, and are then much more comprehensible. In conclusion the formation of local geographical societies for educational purposes is recommended, and an account is given of the formation and working of the Southampton Geographical Society.

2. *Commercial Geography in Education.* *By* E. R. WETHEY, *M.A., F.R.G.S.*

A description of a three years' course of lectures on Commercial Geography to teachers in the West Riding, and of what has actually been done, on the difficulties encountered and on ways of getting over them.

1. *The three years' course*: (i.) The principles of Commercial Geography and their application to the British Empire; (ii.) the Commercial Geography of foreign countries; (iii.) special trades and commodities.

Twenty-five lectures to the course—30 to 40 teachers in attendance; average percentage of attendances 92; centres Leeds and Huddersfield.

2. *The difficulties*: (i.) The inadequate knowledge of general geography the main difficulty, *i.e.* how best to explain commercial results of Physical Geography to minds deficient in knowledge of the elements of Physical Geography. Remedy obvious but not easy of attainment owing to multiplicity of school subjects. Accessories wanted—Government grants for commercial as well as technical or industrial side of education. (ii.) The inadequate notions still existing as to what is meant by Commercial Geography. (iii.) The collection of *appropriate* lantern slides.

3. *A selection of lantern slides* illustrating some of the chief points brought out in the three years' course.[1]

FRIDAY, SEPTEMBER 7.

The following Papers and Report were read:—

1. *The Treatment of Regional Geography.* *By* HUGH ROBERT MILL, *D.Sc., LL.D.*

The author brought a scheme for a geographical description of the British Islands, based on the 1-inch map of the Ordnance Survey, before the Section at the Liverpool Meeting in 1896. He has since worked out the regional geography of the area delineated in two sheets of the 1-inch map of South-west Sussex.[2] The extension to the whole country of work on an equally minute scale appears to be rendered impracticable only by its cost and the indifference of the public to geography. It is hoped, however, that the principles of regional description laid down in the paper may be of service in promoting similar descriptions for other parts of the country, whether carried out as part of a general scheme or independently.

The configuration of the district as deduced from the 1-inch map is the first condition in importance, and should be treated both generally, as to the main features alone, and also specially, as to particular details which are of more immediate interest than the rest. The distribution of rocks and superficial drift taken from the geological map comes next in importance, and it is interesting, though not essential, to trace the causal relation of geological structure and geographical form. It is more important to indicate clearly the places where mineral products of economic value occur. The next part of the description deals with what may be called, in default of a better term, mobile distributions. These include all features

[1] As it would be obviously impossible to show more than a mere fraction of the slides used (nearly 3,000 in all), a further and much larger selection was placed in the Association's temporary museum.

[2] See *Geographical Journal*, vol. xv. 1900, pp. 205, 353.

relating to the surface which are modified in their distribution by the action of fixed forms and particular rock-formations. They include *climate*, the character of which depends greatly on altitude and on the direction of heights and valleys with regard to the prevailing winds; *water supply*, including rainfall, as modified by the altitude and exposure of slopes, percolation and the return of water to the surface as springs (dependent on the geological nature of the ground), and the volume and frequency of rivers, *vegetation, animal life, population* in all the distributional details of birth- and death-rates, disease, migration, towns, villages, and connecting roads and railways, *agriculture, industries*, and *trade*.

The particular case selected was a fairly representative one, and brought out very clearly how all the conditions of human settlement and migration depended ultimately in a more or less marked degree on the forms of the land. It became very clear from such a study that geography rightly conceived was the science which unified and made available for practical application the immense mass of distributional statistics of all kinds which are brought together at great expense by Government, but never coordinated or made available.

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2. *Foreign and Colonial Surveys.* *By* E. G. Ravenstein.

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3. *Military Maps.* *By* B. V. Darbishire, *M.A.*

Our Ordnance map is primarily a military map, made by soldiers for the use of soldiers.

A practical question:—

What is the best form of map for the use of troops in standing camps in this country, or for volunteers encamped for their annual training?

Arising out of this, another question:—

How far do the maps supplied by the Ordnance Survey answer the above purpose?

1. On what points can maps give us information which is useful, and even necessary, for carrying on military operations?

(*a*) Rivers, streams: Width, nature of banks; fords, bridges, ferries, locks.
(*b*) Roads: Width, surface; whether enclosed or not; whether ditches alongside.
(*c*) Railways: Double or single track; embankment or cutting; tunnels.
(*d*) Woods, copses, heather, gorse.
(*e*) Villages: Size, shape; houses, how placed to roads, so as to favour attack or defence.
(*f*) Hedges and ditches.
(*g*) Footpaths.
(*h*) Detached houses.
(*i*) Physical features ('Terrain').

2. Specimens of British Manœuvre maps.

3. The British Ordnance map as a Manœuvre map.
Completely satisfactory except as regards (*i.*) (Terrain) and scale.

4. Representation of relief, various methods used for Ordnance maps.
(*a*) Contours alone. Great Britain, Italy, United States, Switzerland.
(*b*) Shading alone. Germany.
(*c*) Contours with shading. Switzerland, Norway, Austria-Hungary, Great Britain.

5. The Ideal Manœuvre map. Scale; topographical details; Terrain.

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4. *Journeys in Central Asia.* *By* Captain H. H. P. Deasy.

Captain Deasy's paper deals with explorations in Western Tibet and Chinese Turkestan, begun in 1896. The most important features of this explorer's work are, first, the extensive use of triangulation for determining longitudes from peaks, fixed by the Great Trigonometrical Survey of India, and heights; secondly, the discovery of the sources of the Khotan River; and thirdly, the detailed survey of that exceedingly difficult mountainous region, the hitherto unknown stretch of the Yarkand River.

The continued opposition of the Chinese added considerably to the physical difficulties encountered, and resulted in the explorer and his assistant being incapacitated from work by severe illnesses. The latter compelled Captain Deasy to return to India much sooner than he had intended.

It may be of interest to note that the heights of about 250 peaks were determined, and over 40,000 square miles of country surveyed. Much valuable assistance was rendered by the Indian Government, especially by the Surveyor-General, and several officers of the Foreign Department. Captain Deasy is very grateful for this, as well as for the services of the native topographers, kindly lent by Colonel Gore, R.E., now Surveyor-General of India.

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5. *Large Earthquakes recorded in* 1899. *By* John Milne.

In 1899 at Shide, in the Isle of Wight, 130 earthquakes were recorded. The greater number of these were also observed at Kew, whilst very many of them were common to registers from Canada, the Cape of Good Hope, India, Java, Japan, and other distant countries.

Analysis of these records has increased our knowledge respecting the rates at which motion is transmitted through our world, and indirectly thrown new light upon its rigidity. The arcual velocity of surface waves has been investigated, and new rules based on these investigations have been formulated for determining the position of earthquake origins. It has, for example, been shown that the distance of an origin from a given station can be determined either from the interval by which the preliminary tremors outrace the larger surface waves or from the interval between the arrivals of waves which had travelled from their origin round the world in opposite directions.

With this knowledge it is frequently possible for an observer in any part of the world to name the district from which an earthquake recorded at his observatory has originated.

One series of observations showed that the amplitude of the large waves of earthquakes decreased more rapidly when traversing suboceanic paths than when they radiated over continental surfaces. In discussing the nature of large waves this observation on the damping effect of oceans was used as an argument that this form of seismic movement represented gravitational surface waves rather than the outcrop of distortional waves propagated through the body of the world.

One hundred and twenty-five out of the 130 records considered represented disturbances which had suboceanic origins. The principal of them may be grouped as follows:—

1. North-eastern Pacific, W. of British Columbia	14
2. East Mid Pacific, W. of Southern California	5
3. East Southern Pacific, W. of Peru and Chili	8
4. West Pacific, off Japan	19
5. West Mid Pacific, near Java	12
6. Mid Indian Ocean	9
7. North Atlantic, east side	17
8. West North Atlantic and West Indies	6
9. Mid Equatorial Atlantic	5

If we except the second group we see that the Pacific origins are on the face or at the bottom of 'deeps,' which form portions of the trough or troughs around the eastern and western margins of that ocean. If future soundings show that the indicated exception is only apparent, then the second group will also illustrate the rule that accelerations in secular adjustments of the earth's crust are most frequent where this exhibits the greatest flexure.

Inasmuch as there are reasons for believing that each of these earthquakes was accompanied by large mechanical displacements of solid materials, the importance of localising the sites where such changes are frequent is evident to those who select routes for deep-sea cables.

Although we are not in a position to say that these displacements are sufficiently large to produce a measurable effect on the moment of inertia of the earth, attention may be directed to the fact that at those times when changes in latitude have been marked large earthquakes have been frequent, whilst when they have been few such changes have been less pronounced.

Another subject of interest to those engaged in geodetic work is the fact that changes in the rates of pendulum time-keepers may sometimes be traced to the unfelt movements of large earthquakes, which so frequently disturb all countries in the world.

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6. *Report on the Climate of Tropical Africa.*—See Reports, p. 413.

MONDAY, SEPTEMBER 10.

The following Papers and Report were read:—

1. *Railway Connection with India.* *By* Colonel Sir T. H. Holdich, *K.C.I.E.*

The paper deals with the general geographical conditions of South-west Asia which may favour a scheme of railway connection with Western India, the subject-matter of the successive sections of the paper being as follows:—

1. The impracticability of the northern approaches to India leading over the Hindu Kush into Kashmir or Afghanistan from the Oxus regions.
2. The nature of the great transverse water divide of Asia, which includes the Hindu Kush, and the most favourable points for crossing it.
3. The opening afforded by the Hari Rud river to the west of Herat.
4. The configuration of the Persian plateau and mountains, and its adaptation to railway alignment.
5. Consideration of Persian lines of communication with Western India. The coast-line between Basra, at the head of the Persian Gulf, and Karachi. Details of alignment. Commercial and climatic objections to such a line as far as Bandar Abbas.
6. Alternative central line from Western Persia to Bandar Abbas. Difficulties of connection with European systems.
7. Details of alignment between Bandar Abbas and Karachi. Difficulties of coast line, and possibility of interior central line.
8. The proposed connection between Kushk and Chaman (*i.e.* the Herat-Kandahar line). Geographical conditions that exist between Kushk and Herat, and between Herat and Kandahar. Their favourable nature.
9. Objections which have been raised to the line—political and military. Its commercial prospects.
10. Conclusion.

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2. *The Siberian Railway.* *By* C. RAYMOND BEAZLEY.

Short account of the route traversed by the Siberian Railway as far as the Amur. The connections of the railway main trunk with the regions to the north and south, (a) as already made, (β) as in construction and projected. The bearing of the Siberian line on Central and Southern Asia by the intended link, from Tashkent to Orenburg. Primary commercial and industrial purpose of Siberian line west of Lake Baikal. Development of the country: its population, mining enterprises, agriculture, cattle-raising, manufactures, &c., through the movements created by the railway, illustrated by some details. The railway in connection with the river navigation, (a) of the West Siberian rivers, Ob, Yenisei, &c.; (β) of the Kama and Volga; (γ) of the Dvina and Petchora. The railway in connection with the western ocean and inland seas: (a) White Sea, (β) Black Sea, (γ) Caspian. Connections of the railway with Russia's strips of ice-free coast and ice-free ports in the west: (a) on Arctic Ocean, especially Catherine Harbour, near the frontier of Norway; (β) on Black Sea, especially Novo-Rossiisk; (γ) on South-west Caspian, especially Baku.

The railway in its eastern part: different problems here. Highly political aspect of this section. The more recent advance of the line here through Manchuria. The ice-free outlet at Port Arthur, Talien-wan, and the Kwang-tung peninsula. Projects for maritime development of trade to Japan and America from this 'window' as well as from Vladivostok. Connections with China through Mongolia as well as Manchuria.

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3. *On the Possibility of obtaining more Reliable Measurements of the Changes of the Land-level of the Phlegræan Fields.* *By* R. T. GÜNTHER.

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4. *The British Antarctic Expedition*, 1899–1900. *By* C. E. BORCHGREVINK.

Mr. Borchgrevink commenced with an account of the origin of the expedition which he commanded, thus referring to his previous work within the Antarctic Circle, and to the resolution which was carried at the Sixth International Geographical Congress at the Imperial Institute in 1895. The voyage of the *Southern Cross* was shortly described with a few incidents; the results of some of the principal observations (both meteorological and magnetic), the landing, the camp, and the work of the land expedition from March 1899 to March 1900. An account of the principal discoveries made during one year on South Victorian Land was given, with a description of the ice conditions, in winter and summer, near Cape Adare and in the pack.

What the author claims as the principal work of the expedition is the pioneer work in Victoria Land, extending over a period of one year, thus for the first time proving the possibility for an expedition to live on South Victoria Land in the winter, with the following results:—

1. Recording the meteorological and magnetic conditions at Cape Adare and at various places on the ice and on the mainland between this locality and the 78th parallel, thus locating the present approximate position of the South Magnetic Pole, in latitude 73° 20′ S. and longitude 146° E., about 220° west by north from Wood Bay.

2. Discovery of new species in antarctic biology, with special reference to the shallow-water fauna and the flora of South Victoria Land, both proving bi-polarity, and suggesting a theory for the distribution of organisms.

3. Touching upon the importance of the discovery of insects as indicating an average temperature in the neighbourhood of the locality where they were found, not deviating much from what was experienced during the years 1899–1900.

4. Furthest south 78° 50′.

The author gave his views shortly in regard to further exploration within the Antarctic Circle, as well in regard to outfit as in reference to desirable places for landing.

5. *Through Arctic Lapland.* *By* C. J. CUTCLIFFE HYNE, *M.A.*

Finner whale fishing in Arctic Seas—Vardö—Across the Varanger fjord—The start of an eighty-five mile tramp—Boris Gleb—Skolte Laps—Up the Neiden—Arctic Finns—Enare See—Fisher Laps—Enare Town—Farmer Laps—By canoe and swamp—Life on a Lapland Farm—The Arctic mosquito—Herder Laps—Reindeer culture—Norwegian Laps—Rovaniemi—Down to Torneo-Haparanda—The Gulf of Bothnia.

6. *Report on Physical and Chemical Constants of Sea Water.*

See Reports, p. 421.

TUESDAY, SEPTEMBER 11.

The following Papers were read:—

1. *Some Consequences that may be anticipated from the Development of the Resources of China by Modern Methods.* *By* GEO. G. CHISHOLM, *M.A., B.Sc.*

Various causes are pointed out as already in operation tending to bring about that development in spite of the opposition of some sections of the people. These are of such a nature as to make it unlikely that this development, however brought about, will be long retarded.

When it does come about this development is bound to have world-wide effects on a scale of extraordinary magnitude, and in one direction it seems probable that it will tend to reverse the tendency of the last generation in the economic history of the world.

The peculiarity of the position of China is this, that it is the one region in the world with all the means for industrial development on a gigantic scale that remains to be opened up. In the past thirty or forty years we have chiefly seen the opening up of new countries or old countries without great resources for industrial development.

Among the consequences that may be anticipated from this opening up are these:—

1. A rise in prices in China, especially in the industrial regions.
2. The creation of a demand for food-stuffs not likely to be supplied by China itself; a demand which in itself will be one of the most powerful causes contributing to maintain the rise in prices.
3. The imparting of a great stimulus to the food-producing regions most favourably situated for meeting this demand, more particularly Manchuria, Siberia, and western North America, probably the Pacific States of North America to a greater extent than Canada.
4. Perhaps the most important of all, the creation of a tendency to a gradual but prolonged rise in wheat and other grain prices all the world over, reversing the process that has been going on since about 1870 in consequence of the successive opening up of new countries.

2. *The Commercial Resources of Tropical Africa.* *By* EDWARD HEAWOOD, *M.A.*

At least 70 per cent. of the total trade of Africa falls to the countries of the extreme north and south, leaving the whole of Tropical Africa, with an area of some 9 millions of square miles, a total trade of at most 30,000,000*l.*, of which nearly 7,000,000*l.* belongs to the small islands of Mauritius and Réunion. The object of the present paper is to examine the causes of this small commercial

movement as compared with that of other tropical countries, and to form some conclusion as to the permanence, or the reverse, of present conditions.

Among historical reasons for the smallness of the existing trade are (1) the attraction exercised during the age of great discoveries by America and the East and the consequent neglect of Africa; (2) the political condition of the African peoples; (3) the effects of the slave trade; while geographical causes are found in (1) the massive form of the continent and consequent absence of natural means of communication; (2) the unhealthiness of the coastlands. That many of these causes are not necessarily permanent is shown by a comparison with Brazil, which affords a close parallel with Tropical Africa in many respects. This shows that, given natural resources capable of supporting an increased export trade, the commercial future of Tropical Africa need not be hopeless.

The resources of a new country may be classed as (1) exhaustible, principally minerals; (2) permanent, chiefly animal and vegetable products, the second group being the more important. It may be again subdivided into (1) jungle products, which, though not necessarily exhaustible, are likely to suffer diminution; (2) cultivated products. The former may, under cultivation, be transferred to the latter sub-group, which is the most important of all. In Brazil, e.g., the vast preponderance of the exports is made up by the four products coffee, cacao, tobacco, and cotton. Which, with rubber, make up the principal resources of the country. In Tropical Africa jungle products, principally rubber and palm-oil and kernels (total annual value over 4,000,000*l.*), are at present those on which the export trade mainly depends. A period of development of plantation products has, however, set in, and coffee, cacao, cotton, tea, &c., have been grown with success in various parts. The chief difficulties to be encountered arise from (1) want of means of transport; (2) scarcity of labour; but these are now in a fair way to be overcome. The modern tendency for each country to depend for tropical produce largely on its own colonies must favour the commercial development of Africa, while the comparatively low population of Africa per square mile renders it probable that it will in the future play an important part in providing a food supply for the more thickly peopled continents.

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3. *On Snow Ripples.*

By VAUGHAN CORNISH, *M.Sc.*, *F.C.S.*, *F.R.G.S.*

These observations, made in Scotland last winter, are preliminary to a general investigation of the surface forms of snow, which the author proposes to continue in a colder climate during the coming winter. The investigation is undertaken in connection with the author's research upon terrestrial waves and wave-like surfaces.

The general conditions during the following observations are: ground already covered with snow, temperature a little below the freezing point.

Case I.—Snow falling sparsely. In absence of wind the surface was uneven, owing to clinging together of flakes. In a light breeze there was a notable tendency for the prominent parts to arrange themselves transversely in ridges, the distance from ridge to ridge not more than one inch. When the breeze freshened these became regular ripples, with a smoothed surface of closer texture. One set of measurements gave the distance between successive ridges, 1·125, 1·225, 0·85, 1·05, and 1·00 inch. Their amplitude was approximately ·05 inch, which gives a ratio Length : Height = 21 approximately. The steep face of these ripples is on the windward side, whereas in sand ripples and water waves the steep face is on the sheltered side. The normal movement is downwind, the most noticeable feature of the process being the retreat of the steep weather face, consequent upon the abrasion of its surface. For occasional short intervals, however, during lulls and during moments of heavier snowfall, the ripples rush upwind, owing to the sudden deposit of snow upon each weather face.

Case II.—Fresh breeze without snowfall, blowing upon uncompacted snow. The surface was beautifully covered by ripples of 3 inches to 15 inches from ridge

to ridge, which were rapidly increasing in size. The steep side faced the wind. The ridges, which were pretty accurately parallel one to another, were transverse to the wind, but with much sinuosity, no ridge being straight for more than a few inches. It is evident that the wind must be concentrated in the re-entrant angles of the steep weather slope, and this would tend by rapid erosion to destroy the arrangement of long transverse lines which is the most obvious characteristic of ripples. The ridges, however, did not lose their transversality, which was apparently preserved by the greater deposit of drifting snow in these re-entrants, which stopped the threatened gaps; and by the collapse of the overhanging cornice of uncompacted snow at the salient angles, by which these promontories were truncated.

Case III.—The latest-fallen layers of snow having been blown away, the wind acts upon compacted snow (this was generally in drifts which had become exposed owing to change of direction of wind). The wind abraded a fine granular 'drift,' which did not adhere to the smooth hard surfaces. Parallel lines of bevelling or grooving transverse to the wind are the most conspicuous feature of the resulting structure in the compact, almost homogeneous, fine-grained material. The lines are much freer from minor irregularities than the ripples described above. As the action continues, however, the sinuosities are emphasised, for, the 'drift' not adhering well, the re-entrants are cut back more and more behind the salients. Further, the wind concentrating along the lines of the re-entrants, the general level of the surface here is lowered more quickly by abrasion than is the case along the intermediate lines of the salient angles. Thus is produced a well-marked form transitional between snow ripples and *sastrugi*, in which intermediate form the transverse ridges are crossed at right angles by alternate ridges and furrows parallel to the wind, the furrows being along the line of the re-entrants.

Sastrugi.—This action went on until the ridges transverse to the wind were merely a subordinate and scarcely noticeable feature, and the snow was seen to be in great ridges parallel to the wind. These corresponded perfectly with the *sastrugi* of the Tundras as described by A. Penck[1] on the authority of F. Schmidt and G. Bore.

On the opposite orientation of snow ripples and sand ripples.—Ripples in loose sand have their steep faces on the leeward, snow ripples on the windward side. The exposed face of the snow ripple becomes steeper than the sheltered face, because the cohesiveness of the snow while in mass enables the wind to carve out wind caves, in which its force is concentrated. In loose sand the slipping of the material prevents this. The friability of the snow also assists in the effect, the detailed explanation of which would, however, be too long for this abstract.

Observations were also made upon the forms of snowdrifts.

Photographs were taken of ripples, *sastrugi*, and drifts.

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4. *The Geographical Distribution of Relative Humidity.* *By* E. G. Ravenstein.

The author stated that the importance of relative humidity as a climatic factor was fully recognised. Having illustrated its influence upon organic life, upon agriculture and human industries, he expressed his regret that neither in number nor in trustworthiness did humidity observations meet the requirements of a person desirous of illustrating its distribution over the globe by means of a map. This was owing largely to defects in the instruments employed, incompetence of the observers, and unsuitability of the hours chosen for the observations. As to the humidity over the ocean, we were still dependent upon the observations made on board passing vessels, and he was afraid that the time had not yet come when floating meteorological observatories would be stationed permanently throughout a whole year at a few well-chosen localities in mid-ocean. Notwithstanding this paucity of available material he had ventured, in 1894, to publish in Philip's 'Systematic Atlas' a small chart of the world showing the distribution of humidity. The

[1] *Morph. der Erdoberfläche*, vol. i. pp. 388, 389.

subject had not been lost sight of by him since then, and he now placed the results before this meeting. He did so with some diffidence, and over-cautious meteorologists might condemn his action, but they must remember that when Berghaus, in 1838, acting upon suggestions made by Zimmermann and Humboldt, published the first isothermal chart the observations on temperature were even less numerous than those on humidity were at present. His charts, of course, must be looked upon as sketches, but he felt confident that they brought out the broad features of the subject, and to reduce the sources of error he had limited himself to indicating four grades of mean annual humidity, the upper limits of which were respectively 50 per cent. (very dry), 65 per cent., 80 per cent., and 100 per cent. (very damp). The relative humidity over the oceans might exceed 80 per cent., but in certain regions ('horse latitudes') it was certainly much less, and in a portion of the Southern Pacific it seemed not to exceed 65 per cent., a feature seemingly confirmed by the salinity of that portion of the ocean, which exceeded 3·6 per cent.

His second chart exhibited the Annual Range of Humidity, viz. the difference between the driest and the dampest months of the year. In Britain, as in many other parts of the world, where the moderating influence of the ocean was allowed free scope, this difference did not exceed 16 per cent., but in the interior of the continents it occasionally exceeded 45 per cent., spring or summer being exceedingly dry, whilst the winter was excessively damp, as at Yarkand, where a humidity of 30 per cent. in May contrasted strikingly with a humidity of 84 per cent. in December.

This great range directed attention to the influence of temperature (and of altitude) upon the amount of relative humidity, for during temperate weather we were able to bear a great humidity with equanimity, whilst the same degree of humidity, accompanied by great heat, such as is occasionally experienced during the 'heat terms' of New York and recently in London, may prove disastrous to men and beasts. Hence, combining humidity and temperature, the author suggested mapping out the earth according to sixteen *hygrothermal types*, as follows:—

1. Hot (temperature 73° and over) and very damp (humidity 81 per cent. or more): Batavia, Camaroons, Mombasa.
2. Hot and moderately damp (66–80 per cent.): Havana, Calcutta.
3. Hot and dry (51–65 per cent.): Bagdad, Lahore, Khartum.
4. Hot and very dry (50 per cent. or less): Disa, Wadi Halfa, Kuka.
5. Warm (temperature 58° to 72°) and very damp: Walvisch Bay, Arica.
6. Warm and moderately damp: Lisbon, Rome, Damascus, Tokio, New Orleans.
7. Warm and dry: Cairo, Algiers, Kimberley.
8. Warm and very dry: Mexico, Teheran.
9. Cool (temperature 33° to 57°) and very damp: Greenwich, Cochabambo.
10. Cool and moderately damp: Vienna, Melbourne, Toronto, Chicago.
11. Cool and dry: Tashkent, Simla, Cheyenne.
12. Cool and very dry: Yarkand, Denver.
13. Cold (temperature 32° or less) and very damp: Ben Nevis, Sagastyr, Godthaab.
14. Cold and moderately damp: Tomsk, Pike's Peak, Polaris House.
15. Cold and dry:
16. Cold and very dry: Pamir.

The actual mean temperature of the earth amounted, according to his computation, to 57° F., and this isotherm, which separated types 8 and 9, also divided De Candolle's 'Mikrothermes' from the plants requiring a greater amount of warmth.

The author further illustrated his paper by a number of diagrams giving the curves of the temperature, rainfall, and humidity, and also by a chart of the world exhibiting the number of rainy days.

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5. *The Origin of Moels, and their Subsequent Dissection* *By* J. E. Marr, *F.R.S.*

In this paper, the influence of vegetation in modifying hill-outlines is first considered, and it is shown that the concave curve of water-erosion is partly

replaced by a convex curve of weathering on the upper parts of hills, with herbaceous vegetation in temperate regions, and often entirely replaced by a convex curve in tropical regions, where the sides of the hills are clad with forest growth.

The dissection of such round-topped hills or moels by stream action is then considered, and it is pointed out that buttress-like lateral peaks will be formed around the resultant central peak. Lateral peaks of this nature have been described by Mr. I. C. Russell on Mount Rainier, under the name *tahomas*; he gives reason for their production by glacial denudation in that particular case.

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6. *On the Pettersson-Nansen Insulating Water-bottle.* *By* Hugh Robert Mill, *D.Sc., LL.D.*[1]

Professor Pettersson has, in conjunction with Professor Nansen, completed a modification of his well-known apparatus for obtaining samples of sea-water without change of temperature. A specimen of the improved water-bottle constructed by Messrs. Ericsson, of Stockholm and London, was exhibited. The purpose of this apparatus is to enclose a quantity of sea-water at any desired depth, to hold it securely, and to bring it to the surface without any change of temperature exceeding one hundredth of a degree Centigrade. The previous form of insulating water-bottle was found by Dr. Nansen in his arctic expedition to be less trustworthy at great depths than in shallow water; hence the suggestions which resulted in the new apparatus. The insulation, which is the essential feature of the water-bottle, is secured by a series of concentric chambers of non-conducting material which are simultaneously filled with water, and so protect the portion, measuring about two litres, which occupies the large central tube. The walls of the inner tubes are so constructed as not to become heated by compression at the greatest depth. This is secured by using metal, which is heated by compression, and indiarubber, which is cooled by compression, in such proportions as to ensure constancy of temperature for the whole structure.

The water-bottle when set is held apart, so that the base, sides, and lid are separated, and the water passes freely through the tubes as the apparatus descends. When the apparatus is being drawn up a propeller (which during the descent revolves freely) engages with a screw and releases a heavy weight, which closes and locks the whole rigidly together. An arrangement is provided for the relief of pressure as the included water expands on being hauled up. The temperature is ascertained by a thermometer, protected againt pressure, enclosed in the central tube, and projecting sufficiently far to be easily read. If preferred, the aperture for the thermometer may be closed by a screw and the thermometer inserted when the water-bottle is brought up. A reversing thermometer to give the temperature of the water independently may be attached to the upper part of the water-bottle, and is set in action at the moment of closing. The whole apparatus weighs about 58 lb., and is used on a wire line and worked by a steam winch.

During August of this year the improved water-bottle was tested by Professor Nansen on board the *Michael Sars* in the sea between Iceland and Spitsbergen, and at the greatest depth met with (3,000 metres = 1,670 fathoms) the insulation was perfect. On August 11 a sample was taken from 3,000 metres, and when it came up the thermometer read: 1°·285 C., after five minutes 1°·283, after nine minutes 1°·270, and after eleven minutes 1°·210. On August 13 in a sample from 2,000 metres the thermometer showed 1°·135, after five minutes 1°·135, after six minutes 1°·130, and after eight minutes 1°·110. Professor Nansen considers it essential to use an included thermometer.

[1] Published in full in the *Geographical Journal*, vol. xvi. (1900), pp. 469–471.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section—Major P. G. Craigie, V.P.S.S.

THURSDAY, SEPTEMBER 6.

The President delivered the following Address:—

The 'Advancement of Science' is the motive wherewith the British Association brings annually together, in autumnal conclave, a gathering of those who desire to tell and those who wish to hear something of the most recent developments of scientific labour. Entrusted for the session with the high honour of presiding over a Section where the chair has from time to time been occupied by a long roll of distinguished men, whose qualifications for the task necessarily far outstrip any I could pretend to claim, I may yet follow the example set by such authorities in maintaining on your behalf, and on my own, that the right production, the proper treatment, and the wise grouping of garnered facts concerning man and his relations to the State as a member of society constitute a study second in importance to no other form of research. Moreover, such expert discussion of statistical methods and statistical results as ought to be possible in this Section should, I think, prove a factor of no small moment in its bearing on the true advancement of Science in its broadest sense, whether physical, economic, or political.

Without the claim to speak to you on the lines which could be appropriately adopted by some former Presidents, who have held positions of eminence, won either in the highest fields of politics or earned by patient work in the cloistered retreats of academic study, I come here rather to represent those who form, as it were, the hewers of wood and drawers of water for the economic controversialists of the day. As such we are concerned in the daily outturn of raw statistical material, and we are naturally jealous as to the use to be made of our figures by those who employ them in the process of scientific deduction, in the business of practical administration, or in the efforts of philosophic teaching.

Whatever be the precise meaning we are willing to accord to the term of 'statistics'—and both the primary interpretation and the proper scope of the expression have been differently construed—I believe you will agree with me in echoing the opinion expressed, I think, by a very distinguished past President of this Association, that nearly all the grandest discoveries in science have been but the rewards of accurate measurement and patient long-continued labour in the sifting of numerical results.

Not only thus may we claim for what is sometimes looked upon as the merely mechanical part of statistical work a directly educational effect on the honest workers themselves, in the training and discipline of mind which are required for the handling and weighing, the balancing and comparing of numerically arranged facts; we may go further and assert that every science in its turn has occasion to

rely on the statistician's art, and that the true advancement of knowledge in whatever path we take depends quite as much on the avoidance of rash conclusions as on the faculty of quick perception of apparent results.

There is then this lesson to be learned in the discussions to be held in this Section, and it is one on which, in opening our deliberations, I think I am fairly entitled to insist. Since accurate statistical data are fundamental to sound argument and correct deductions in any sphere of science, too great care cannot be expended in the task of making sure that figures given to the public are really what they claim to be. Where a comparison is to be made it is our business to see a practical identity in the character of the facts to be observed, and to give such warning as is requisite to guard against the possibility of over-strained and illegitimate use of the data by those into whose hands they may ultimately come. Where a deduction is to be made or a conclusion is to be announced by the original compiler himself, it is well, too, he should remember that a statistical decision should have in it something of judicial deliberation and gravity, and should be given to the world only after the application of a chastened scepticism and distrust to the testing of the first impressions to which the bare numbers that appear on the surface of any calculation seem to point.

Lastly, let us not overlook the prescriptive cautions of many past masters in statistical work to distrust big totals and dissect general averages.

We are all of us familiar with the vastly larger space accorded to statistics in debate in the second half of the dying century, how readily the arbitrament of figures is now appealed to by the politician or the journalist, by the man of science or the philosopher. This very fact, however, constitutes in itself a danger, and I trust, therefore, I may be forgiven if I interpose between the Section and its prepared work by preaching from the Chair with some insistence the somewhat trite doctrine that statistical and economic science has few greater enemies than those who fail to apply the most rigid tests to the sufficiency of the elementary figures on which a theory is to be formed or an administrative act accomplished. Nor, indeed, is a much smaller offence involved in the over-confident use, whether for international comparisons or for those flights of prophecy in which we all like from time to time to indulge, of figures not in their immediate connection themselves erroneous, but which are, nevertheless, not quite strong enough to bear the strain of the superstructure to be reared, or which are devoid of the essential elements of true comparability of condition.

It is then alike for the makers and the users of statistics to observe much caution in their own utterances and in the manufacture of those missiles of controversy which every table furnishes, and which in the hasty discussions of our day, when mere rapidity is exalted almost to the place of a virtue, are apt at times to prove dangerous to those who wield them, whether in the press, the lecture-room, or the senate.

Most of all is it incumbent on one who ventures on the duties of this Chair with none of the opportunities of reflection which many professorial predecessors must have enjoyed, and who comes straight from the daily turmoil of executive work and the discharge of continuous official service, to exercise some reticence in venturing on expressions of individual opinion. In what I may say, therefore, by way of preface to your discussions I would endeavour to confine my remarks to a notice of some of the chief statistical investigations now impending and an account of the difficulties to be encountered by the statistician in his work, illustrating, from the class of subjects with which my work has made me familiar, the sorts of obstacles which hinder the accurate presentation of international comparisons of agricultural conditions.

The entire omission of a sectional address—for which there is, I believe, precedent in your records—or the substitution of a simple speech for a reasoned paper, as was allowed to the distinguished statesman who presided at the last Bradford meeting, on the score of the demands of the State on the services of its servants, might, perhaps, have met my case and relieved me of a duty to which I feel far from equal, and you of listening to my crude remarks. This indulgence has not, however, been accorded, and I must, therefore, crave the pardon of the Section I can

only serve so badly, and urge its members, in the later discussions, to supply the shortcomings of the occupant of the Chair.

Of all statistical work the enumeration of the units of population must ever take the foremost place, and on the eve of the census to be taken before many more months have passed a reference to that great impending task could hardly be omitted on this occasion. In common with all students of the machinery of census-taking I am sure I echo the feelings of the Section—as I do those of the Royal Statistical Society, who have long laboured in this direction—in deeply regretting that the first census of the twentieth century is not to possess the distinction many had hoped to see conferred upon it of being by preliminary announcement—as I hope it may prove to be in ultimate fact—the first of a series not of decennial but of quinquennial countings of the people.

The growing complexity of social conditions and speed of life in all its functions at the present date, contrasted with the leisurely movements of a hundred years ago, would alone and amply justify a more frequent stock-taking of the inhabitants of Great Britain than has been the practice in the past. The practical wants of our much-multiplied system of local government cannot fail, I believe, ere long to bring about the granting of an intermediate numbering, even if for the moment other considerations overrule the more academic pleas of statisticians for this reform, or the arguments, sound as I believe them to be, for a permanent Census Office, a permanent Census Act, and a trained and continuous Census Staff, to whom preparation of the machinery beforehand and detailed elaboration of the results after the actual census year might with real economy be entrusted.

Like probably many another student of practical statistical organisation, I have to own to some modification of the demands for enquiry into the condition as well as the numbers of the people, which I once believed might be properly combined with the actual operations of enumeration. Some little experience in measuring the extent and the value of the answers elicited by question and by schedule have shown me that with due regard to the quality, if not even to the quantity, of the replies extracted from the least instructed section of the population, you must limit your curiosity unless you are to be landed in doubt, in difficulty, and in misconception.

Specific and parallel enquiries in point of time by one or another central body may no doubt be devised and directed so as to bring out a definite and limited series of facts, affording matter to be compared with population totals. But to load the census proper with side issues is not to help forward the best type of statistical knowledge, and the attempt may well be pushed too far. I fancy there is now some reason to believe that ten years ago we erred in this respect. For these reasons I have never in recent years been able to go along with many active and highly intelligent foreign colleagues, whose more sanguine aspirations as to possibilities of what a census can tell it is always pleasing to witness, even if the feasibility of their suggested developments may be questioned.

Sound and reasonable advice on such a subject may be found in the timely remarks of my colleague Mr. J. A. Baines, in his paper to the Royal Statistical Society in February last on the 'limitations' of census-taking. From no better or more practical source could we hope to be instructed on what can and what can not with advantage be got than from the able officer whose superintendence of the vast Indian Census of 1891 brought him such widespread recognition.

The mention I have made of the suggestions of foreign statisticians on census-taking reminds me that although the proposal which has been before the International Statistical Institute in one form or another for a synchronous 'world's census,' at the moment of passing from one century to another, is hardly likely, for administrative reasons and in view of the previous fixtures of the great census-taking Governments of the earth, to be literally realised, the dates of the great countings of the nations will nevertheless come sufficiently close for all practical comparisons. The great Russian enumeration, on the success of which M. Troinitsky is so heartily to be congratulated, is not yet long accomplished. The twelfth census of the United States is now being taken. The Scandinavian enquiry

coincides with the century's end, the Italian and the Spanish censuses are already overdue, and both France and England take their count within a few months after the twentieth century has begun.

Not persons only, but their conditions, their possessions, their trade, and their burdens are all subjects of perennial statistical enquiry, and in connection with the last of these groups in the near future the attention of statistical critics will no doubt be drawn again to the massive collection of materials respecting local taxes, their growth and pressure, which may be looked for from the final report of the Royal Commission on Local Taxation. How many times in the last half of this century this section of our finance has been debated here I have not been able to ascertain. In one form or another it has exercised a fascination on the minds of some of our most active economists. Personally I confess the field was one of the first in which I ventured to make some enquiry and draw tabular comparisons. To this I was incited by the study, not at first of the second-hand stores of the many blue-books which have seen the light on this matter, but rather by the peculiar circumstances of my local residence in a Yorkshire township four-and-thirty years ago, when local government and local rates of necessity came home with primary concern to one who happened, like myself, to be the sole inhabitant householder of an area constituting for several purposes a unit of local administration.

I cannot pretend to have followed through the later years of the century the wider developments of these controversies, which were far from simple even in the days when the issue was limited to a question of pressure of the ratal system on agricultural land. Now, when the vast and complicated outlay of the great urban centres on matters which, in time past, we were not disposed to regard as subjects of taxation at all, but rather of directly remunerative outlay, has to be brought into the survey, it may well tax the ingenuity of our younger statisticians to unravel the facts, and it may try the courage and the skill of the economists to pronounce, as this Section may be expected to do before its sittings close, as to the orthodox limits and sphere of ever-extending municipal expenditure and municipal trade.

The statistical part of such enquiries as these will abound with problems in the working out of which it will be well to recall the warnings I have indicated as to the danger attending the use of non-comparative or defective data. Pitfalls innumerable await the less wary controversialist in such questions as these, which seem near at hand, while yet wider discussion on the relative pressure and comparative growth of taxes generally may erelong attract renewed attention, as well as the subjects of statistical debate which centre round the records of crime and its punishment, of educational facilities and the economic results of their supervision by the State, or, again, of excursions into the intricate region of labour and wages, wherein some of our section have already pursued useful investigations. In all and every one of these topics the scientific statistician will have to remember that his profession does not allow him to be a partisan advocate of one or the other view, in search of some figures to illustrate or decorate a predetermined theory. On the contrary, his function is to work in the cold, clear light of pure scientific research, and with a single aim to free the facts of each case from obscurity and place the data before the world in such shape as to allow a true judgment to be recorded.

Quite as full of difficult problems and obstinately non-comparable figures will be found to be the use of statistics of production and of trade. The varying and scanty records of one period may have to be viewed in connection with and interpreted by the better and fuller data of the day, and the conditions of one country may have to be contrasted with those of another, while the puzzling variations in the system employed have to be allowed for and discounted in the conclusions.

Perhaps the difficulties of just comparison between the records of one time and another, or one State and its neighbour, come home to me with peculiar emphasis when the statistics dealt with relate to agricultural conditions. With ourselves

and still more in certain quarters abroad regular agricultural statistics are of quite recent birth.

It is difficult, perhaps, for us now to recall the comparatively recent origin of comprehensive statistics of agriculture in Great Britain. Writers of note, economists, and philosophers had no doubt from early times ventured to make estimates of more or less individual authority on the probable magnitude of our agricultural resources. Expert witnesses, with more or less opportunities of individual observations, came before Parliamentary Committees with rough impressions of the extent of our cultivated area and the distribution of the crops which it bore. The labours of the old Board of Agriculture, which existed at the end of the last and for a few years at the beginning of this century, amassed, no doubt, much valuable though scattered local information and many details of farming practice, but they completed no such exact survey as would have proved invaluable now to the statisticians of 1900 respecting the use made of the soil of our country a hundred years ago. The erroneous estimate of 47,000,000 acres of total area assigned to England by the Chairman of that Board, when later data proved the measurements to yield 10,000,000 acres less, is a warning of the care which is needed in the use of such figures as were available in those distant days

After efforts more or less spasmodic in 1831, again in 1845, and yet again in the more complete work of the Highland and Agricultural Society of Scotland in 1854–7, encouraged by the verdict of the House of Lords' Committee of 1855, and fortified by the repeated recommendations of International Statistical Congresses, the House of Commons was, in 1864, persuaded by Sir James Caird to pass a resolution for the establishment of annual agricultural returns. These were first collected in 1866, and one year later they took the more complete form which gave us the continuous records Great Britain now possesses for tracing the development or retrogression of our country in agricultural conditions throughout the last third of the nineteenth century. The data thus obtained must, of course, be read with full allowance for some minute but inevitable variations of definition due to the gradual improvement and growing completeness of the returns themselves, first under the Board of Trade, then under the care of the Privy Council, and now under the Board of Agriculture.

Agricultural statistics, whether in this or other countries, are assuredly not exempt from the need of careful and intelligent handling and of caution in drawing comparisons. The leading features to which any agricultural enquiry is directed are naturally the extent and characteristic modes of the occupation of the surface, the number of persons engaged and the size of their holdings, the area and yield of the distinctive crops, and the numbers and classes of live stock. Some of these points can, and others with advantage cannot, be made the subject of direct annual enquiry and compilation. But in all cases questions as to precision of definition arise when the careful investigator looks below the surface to see what the figures really mean.

The total measured areas of the countries we desire to contrast may, it is true, be fairly accurately given, though even here there is room for error, in regard to the practice of including or excluding areas covered by inland and tidal waters, lakes, and rivers. When the next step is taken, and it is desired to contrast the respective areas actually made use of for productive purposes, difficulties of comparison at once present themselves. The phrase 'cultivated' area in our country is one to which, at least in unofficial if not in Government publications, two distinct meanings are often attached. The term is sometimes used as if in some sense synonymous with the arable surface, whereas in the other, and with us by long tradition the official sense, the term covers all land, other than woodlands or rough wastes and mountain grazings, utilised for agriculture, whether under the category of permanent grass or under yearly varying crops.

Nor is uniformity of practice much greater as regards the methods of returning the actual agricultural population. The number of persons actually employed, male and female, may as a rule be distinguished, but all countries are not agreed as to what employment means. The practice as to who are and who are not to be regarded as dependents, or as occasional and casual workers, may vary greatly. In all countries, and perhaps rather more abroad than here, there are

many persons who combine an agricultural with some other calling, and this in an infinitely varying degree. The German and some other statistics endeavour laboriously to give tables which take account of these persons with double occupations and allot to them a place under more than one head. In England we have no provision in our census for these cases, and a farmer and brewer or a labourer engaged sometimes on a farm and at other times at other work may be classed by the accident of the first entry in one or other category at random.

By what is nearly a common consent, the attempted enumeration of the agriculturally occupied population is connected rather with the general enquiries of the census than with the crop returns of each year. Its value of necessity depends on the coincident and relative record of the occupations, other than agricultural, in which the inhabitants of any country are engaged. Such considerations supply the answer to some of our less reflective writers on this question, who would have a perennial investigation going on into the available supply of agricultural labour—year by year, if not month by month. The movement in the direction of concentration of growing numbers of the workers of a nation in the urban districts, which is apparent in so many countries besides our own, and under the most opposite conditions of Governmental polity or agricultural organisation, will no doubt form in a short time a very interesting topic of statistical discussion. But the general figures cannot be handled with very great advantage now at the distance of wellnigh a decade from the last enumerations and at the moment when the taking of a new census is at hand. Until that enquiry reveals its facts, the student of questions of relative rural population may be referred to the mine of information collected by the Royal Commission on Labour, and the late Mr. W. C. Little's admirable and exhaustive analysis, and to the most valuable statistical buff-book which the Board of Trade have just issued from the pen of Mr. Wilson Fox.

Equally or even more full of pitfalls for comparison are statistics of the size of holdings, whether the comparison be made between one date and another in a country like our own, or between one country and another. Not only will the grades employed necessarily vary between country and country, but the starting-point and definition of what is a 'holding' is usually entirely different.

In one of the earliest meetings of the International Statistical Institute at Rome I drew attention to the barrier thus offered to international comparisons on the latter point. I then showed how occasionally it may happen that the recognised 'holdings' seem to have included every plot, however minute. Germany and Belgium, and I may add Ireland, apparently made a beginning at zero. Great Britain at one time regarded a quarter of an acre as a limit of statistical enquiry, although since 1892 restricting the term 'agricultural holding' to something over an acre of land. Elsewhere, as in Holland and in the United States, refusals, except under specially defined conditions, to take anything less than a plot of two and a half or three acres in extent as a starting-point in the agricultural enumerations are encountered.

It is not always remembered that we ourselves have, even within the comparatively brief course of our official agricultural returns in Great Britain, held more than one opinion as to what the starting-point should be. At the first collection of these statistics nothing under five acres was taken account of as agricultural. The scope of the annual enquiry was subsequently extended to plots of a quarter of an acre, and the limit was raised again eight years ago to the present requirement, which refrains from requesting annual details of the acreage of their crops from the occupiers of holdings of a single acre or less. As a matter of administrative convenience there is very considerable advantage in the course now pursued, and no real statistical loss is involved, for the land occupied by the various petty crofts or gardens which escape annual record was found not to reach one-tenth of one per cent. of the cultivated area, and such rare changes as might occur in the crops raised on these minute sections of territory could in no perceptible degree affect the value of the returns as affording a general view of the current change of agricultural practice. Changes, however, in the unit of

area, as well as changes even in the direction of improvement in the machinery of collection, are all hindrances to very close and accurate comparisons.

Attempts have no doubt been made to enumerate separately the strips of land held as gardens or allotments, at different dates, in England, but considerations such as I have above indicated have rendered the results of much less statistical value than can be claimed for the yearly returns, and the failures of some of these repeated attempts furnish a conspicuous warning against overloading the never very simple task of rural stock-taking by too frequent and necessarily costly enquiries into very minute points of agricultural condition.

Even in records of the numbers of animals there is room for much misunderstanding. 'Horses' are defined differently in the returns of different countries, at one place the numbers including trade and private horses, in another only those engaged in agriculture. The ages and the classes of the animals, and the dates of the collection again, may and do vary considerably, and this may bring in lambs in one country and omit some portions of this group in another. Even cows, it is found, may mean one thing in one country and another in another, and may be returned with other cattle in a single class or shown separately from other horned stock. Oxen are shown in some countries with no distinction of class or age; in others those still used for working the farm may be distinguished from those reared for purposes of meat production only. All these cautions are only examples of the danger of venturing on too close reliance on data of this kind in international comparisons.

Over and above all difficulties due to difference of agricultural practice and local definitions, the most serious bar to exact comparison of the course of agriculture in different countries is the widely varying practice as to the intervals at which statistics are collected. Live stock may be enumerated, as with ourselves, in France, or in the United States, annually, while wide gaps occur between the years of stock-taking elsewhere. The acreage of each crop in each season may be recorded in one country; in another five or ten years, in some cases even fifteen, may elapse between the enquiries on this essential point, and estimates of produce checked by no local examination of the surface occupied too often prove delusive guides to the results of particular years. These gaps are the dread of any one who sets himself seriously to examine what has been the general movement either in the changing areas of crop distribution or in the relative growth or decline of agricultural production abroad.

Continuous annual data of acreage, production, and live stock ought, however, to be within the reach of most fully equipped Governments of modern times. The method of the collection will necessarily differ. Information obtained direct from the immediate producer by written schedule is perhaps available nowhere but in our own land. The fact is one which says something for progressive intelligence and the general support which the State receives from the great bulk of farmers of Great Britain, and the working of our system has attracted much attention of late from those responsible for the conduct and development of agricultural statistics in foreign countries. We may pardonably view our position in this country with satisfaction when it is recognised how largely foreign correspondents are yearly seeking for more and more information as to how so big a statistical operation is annually accomplished here between June 4 and August 28 in the time and with the machinery at our command. To the statisticians of Russia, Spain, Italy, Germany, Denmark, and even of Japan we have had lately to explain our process. Could some approach to this system be obtained, the means for accurate measurement of the world's agricultural movements would be greatly helped, and it may at least be hoped that a generation hence facilities will abound for a closer review of the position of food supply and production than is now feasible. But it is not necessary to wait quite so long for some general glimpse of the facts. Already in France, Germany, Austria, Hungary, Roumania, Russia, and the United States among foreign countries, in our Indian possessions, and in our Australasian colonies, we find indeed annual statements—not all, however, collected similarly—of the area under the principal grain crops. Two only of the provinces of the Canadian

Dominion venture on annual returns. Annual, if later, figures reach us from the smaller States of Holland and Sweden, and from Algeria and Japan.

It is not for us here, like amateur war-critics distributing praise and blame from our armchairs on statisticians engaged in local conflict with the difficulty of crop-collection abroad, to forget the relative compactness of the area of these islands and the relatively developed intelligence of an agricultural population farming, on the average, larger holdings than most of our continental neighbours. We ought not, therefore, to refuse to appreciate the difficulties, administrative and financial, which a close adoption of anything like the British system would involve, either where the peasant population is predominant or where the areas to be accounted for are vast, as in the United States or in Russia.

It is, I think, in the circumstances not illegitimate to use, at all events for comparison of the state of matters within the same country, the data which are now available from year to year. With less confidence we may even quote, as presumptive indications of the directions of movements, the isolated returns of acreage for particular years which alone some States supply. That there is peril, however, in such a course may be seen by what is proved to have happened in a country like France, whence we do receive continuous data. For the past quarter of a century the acres devoted to wheat in France have been practically the same, 17,000,000 acres. One single exception appears, however, in the season of 1891, when under exceptional climatic conditions an area of only 14,000,000 acres was reported. Now, had France rendered only occasional acreage records, like her Belgian neighbour, like Denmark, or like Argentina, and had the year 1891 chanced to be the date of the enquiry, an investigation of the rise or fall of wheat culture in Europe might have been deflected from a true conclusion by the deceptive record of a state of matters occurring only once in a single exceptional season, and immediately recovered from.

In any attempts which may be made, even within the period of fairly reliable agricultural statistics, to trace the features of the changes of the past twenty or thirty years, it is necessary to remember that, as between one country and another, the data can be received only with much reserve, and as strictly comparative, if even that, only within the respective States compared at different dates.

Attempts to utilise statistical data, to determine the relative development of agriculture in different parts of the world and at different periods of time, are sometimes made with regard solely to what is described as the world's aggregate of one or two leading individual products as typical as the rest; or, again, one or two typical countries, or at least countries where the available information is more complete than elsewhere, are chosen, and the course of development or decline of their crop areas or the several descriptions of their animal produce is traced and compared.

Certain obvious objections, which it is well to recognise, impede the student of figures who resolves to proceed on the first of these methods. At the outset he is arrested by embarrassment attending the choice of what single products are to be held as representative of agricultural outturn. The most usual of all selections is that which restricts enquiries to the case of wheat. This course appears to be rendered, comparatively speaking, easy, as more has probably been written and more statistics, official or unofficial, theoretical or commercial, actual or imaginary, have been compiled, with regard to this bread grain than for any other crop. But it is time we recognised that wheat has had too much and too exclusive attention directed to it as a type of agricultural production. Very widely as it is undoubtedly used in the form of bread, even as food its place is occupied at one time or another, and in one country or another, by other substitutes, and its cultivation is, after all, not the employment which demands the most attention and most skill at the hands of the agriculturist. Not only do rye and even maize serve as substitutes or supplements in feeding man, but other crops, such as oats, barley, millet, rice, and so on, have claims to greater notice than they receive, and play a direct as well as indirect part in providing food. Cotton, flax, and wool are other typical products, the use of which for clothing is all-important

to an enormous population, and the extension or retrogression of such crops deserves some of the attention of the agricultural statistician. Tea, coffee, wine, spirits, and beer are, it is not to be forgotten, agricultural products in one clime or another, either directly or indirectly; and crops so important as sugar or tobacco are almost to be classed as necessaries of existence. Of yearly growing importance is it also, in these days, when the animal portion of our food supply bulks so much more fully than before in the daily rations of populations as they grow in wealth and increase in consumptive power, that we should closely follow the fluctuations in the live stock maintained for food and learn the teaching of the agricultural returns on the manufacture of beef, of mutton, of pig meat, or of milk.

The growing requirements of our 40,000,000 of population in this country—dependent for a large proportion of their meat on cattle, sheep, and swine fed in other lands and in some of the most distant countries of the globe—have provoked a series of enquiries into the extent of our domestic production and the density of the herds and flocks maintained on like areas of the surface of the other and different regions.

It is half a century since Sir James Caird, in calling the attention of farmers to what he foresaw was the certain growth of the demand for butcher's meat, for milk, and for butter in the United Kingdom, argued that as the expenditure of the lower classes increased the development of household outlay with increasing means would necessarily take this direction. Venturing a little beyond the safe ground of statistical deduction as to what was forthcoming from our own stock, it is true he prophesied that it would not be found practicable to import fresh provisions coming from distant countries, and he therefore suggested that the enterprising home producer would have the full market here practically at his own command. The same authority repeated in 1868 his advice as to the direction the development of agriculture here might take, placing the extent of the reliance of the British consumer on the foreigner at only one-ninth part of his supply of meat, and one-fifth of his consumption of butter and of cheese. That these ratios have altered since, to the detriment of the producer, if to the benefit of the consumer, assuredly does not render the need of statistical enquiry into meat and milk production less urgent than it was as a most important factor in the nation's food supply.

Sixteen years ago, when this Association met at Montreal, I ventured to lay before this Section some data on the nature and extent of our meat supplies and the scale of our production, based in the latter case mainly on the very practical investigation of a former President of the Royal Agricultural Society—Sir H. M. Thompson—but adapted to the data of the current agricultural returns of live stock. For numerous purposes the formula I then employed has since been followed as convenient for serial comparisons of annual results in the statistics founded on reports by Royal Commissions and Parliamentary Committees. But no student of statistics will contend that the conditions of agricultural production are ever absolutely permanent, and I have seen there are not wanting opinions that it may be needful, from one cause or another, to revise the scales of the calculation, and to compare the most recent rate of meat production in this country with that of other lands.

Few subjects seem to me to possess more practical interest for those willing to aid in statistical research, competent to apply to the numerical data a corresponding knowledge of the development of stock-feeding in recent years and in different countries. I commend a re-investigation of this subject—and the kindred one of milk production and the manufacture of dairy produce in this country and abroad—on the lines in the one case of the inquiry of 1871, and in the other on the lines which Mr. Rew suggested in a paper in 1892 to the Royal Statistical Society—to the best attention of a younger generation of estimators. Whether and how far the earlier maturity of our present breeds of sheep and cattle and swine has resulted in the production of a larger annual volume of meat is a factor which should have careful consideration, and if a careful inquiry should suggest the time for revision has arrived respecting the 67 tons of beef, the 12½ tons of mutton, or the 69½ tons of pig meat I and others have hitherto used as the equi-

valent of the annual production of 1,000 animals of each type respectively I should not be unprepared to make whatever change is proved needful, despite the reluctance with which every statistician forsakes, even on good grounds, a basis of conversion which has served without break of continuity for the comparison of more than thirty years.

How largely the demands of a population like our own have upset the old proportions of our reliance on imported meat and imported milk products may be learned from the fact that the latest calculation which I have made suggests a meat consumption of no less than 132 lbs. per head in the United Kingdom, against a little over 100 lbs. thirty years ago, more than two-fifths of the whole now reaching us from foreign countries or British possessions, against the ninth part at which Sir James Caird estimated the foreign quota.

The mention of these meat estimates suggests a reference, by way of illustration, to the extremely interesting and legitimate application of the important deductions from purely agricultural statistics possible when once the temptation to narrow the question to one of wheat production and wheat supply is resisted, which was made by my colleague, Mr. Crawford, in a paper read to the Royal Statistical Society last winter. The calculations made dealt with the relative dimensions and sources of the food supply of the United Kingdom, France, Germany, and Belgium. The deductions made from the data available, and the useful discussions thus provoked—including a supplementary memorandum by Mr. Hooker on the relative forces occupied in production under the differing conditions of British and Continental farming—are replete with interest to the future investigator who is willing to face the labour of looking below the surface either of agricultural statistics or of import or export returns into the economic meaning of the situation thus disclosed. No lesson, perhaps, of this paper is more worthy to be remembered than the warning which it gives to the class of writers who, without a due appreciation of the facts, are as ready, from the vantage-ground of the editorial chair, to fight the battle of the agriculturist for him on paper, as to teach our generals how to handle a British army in the field.

But for considerations often overlooked, which were on this occasion put forward, the abolition of our dependence on sea-borne produce, it is sometimes argued, could be procured by a simple extension of our own agricultural area. What that extension would have to be it is now shown is something much more serious than many imagine. It is not alone that to fill the gap of our imports of wheat and flour would take another 6,000,000 acres of the prolific quality of our own, but the direct production of the imported meat and dairy produce and of the numerous feeding stuffs required for the manufacture of our present quota of animal food raised at home would at the most modest computation necessitate 17,000,000 acres more to be added to our productive area, and that, be it remembered, without withdrawing any portion whatever of our present surface, which, whether under crop or grass, helps to sustain our outturn at the present level. The prospects of a practical annexation of this aggregate of 23,000,000 acres to those now under cultivation at home I confess do not seem to me great.

Although the attempt to grasp the relative magnitude of the agricultural production of one State as compared with another, or to note the growth or decline of its prominence in the cultivation of particular staples, or the manufacture of particular kinds of human food, is always an enterprise of difficulty in existing statistical conditions, it is one which has fascination for many classes of economists and politicians. If attempted at all it is well to recognise that there are inevitable dangers in the task, and that if any figures are relied on as conclusive their meaning must be interpreted by some knowledge of the demographic conditions of each State and its geographical, climatic, and agricultural circumstances.

Taking a few of the most conspicuous products of the soil, it will generally be found that a very few leading States are so particularly identified with one or other type of production that the examination of their records is therefore available as a guide to the course of a single crop.

Probably quite two-thirds of the cotton of the world is grown in the United States alone, where the surface so employed reaches 25,000,000 acres as compared with under 9,000,000 acres in British India, the next largest cotton-growing region of which statistical record exists. In wool the produce of the Australasian Colonies of Great Britain—with flocks which still exceed 100,000,000 head—makes much the largest contribution to the total. In rice, so far as statistics carry us, our Indian possessions head the list of producers. In hops the English crop still probably exceeds the German in production, although the latter with larger area closely contests the place. In tobacco, while the acreage apparently employed in British India is nearly double the 595,000 acres in the United States, no other country in our statistical records comes within one-seventh of the American area. The vineyards of Italy are returned as covering 8,500,000 acres, and those of France 4,300,000 acres, while those of Austria and Hungary, next in magnitude, cover but a seventh part of the last-mentioned figure. Russia bulks largely as a grower of flax, and alone shows a whole third of the area of barley recorded in all the countries which supply returns, and if in the case of potatoes the Russian acreage is not very different from that of Germany the total production of the latter empire reaches the largest aggregate of any single country.

If the subject of enquiry be the place of wheat-growing in the world at one date or another, it would not be to the older European countries, other than Russia at all events, we should turn to see where the surface so utilised was extending. Reckoned by the percentage of her cereal area which she still devotes to wheat, France, with 47 per cent. under the crop, or Italy, with 55 per cent., would naturally be selected as typical wheat-growers; but both are practically in a stationary or, collectively, even in a slightly retrograding position. It is on the other side of the Atlantic where the most noteworthy movements have occurred. In comparatively new exporting countries, such as Argentina and Canada, though the statistics from neither are complete, wheat areas still extend, and that of the United States, though fluctuating with great sensitiveness under varying price conditions, and moving from one centre to another westward or northwestward across the American continent, is now reported as covering 44,600,000 acres. This total, it must be allowed, whatever views may be held as to future progress, makes the United States a typical grower of this particular cereal, to which it gives an importance second only to the still more extensive product of American soil, to which we give the name of maize, but to which alone in American parlance is allowed the title of corn.

The leading changes in the production of typical crops as measured by the acreage, and the stock of cattle, sheep, and swine recorded at or near the commencement, the middle, and the close of the past thirty years, may be contrasted for exporting countries with expanding populations and growing agriculture, and in countries where these conditions are absent, or in a typical consuming centre like our own country. Relying on the agricultural returns of the United States, a table could be constructed, as under, for three dates within the past thirty years which furnish the following indication of agricultural changes:—

United States	1870	1885	1899
Population, in million persons	38·6	56·1	76·0
Area under maize, in million acres	38·6	73·1	82·1
Area under wheat "	19·0	34·2	44·6
Area under oats "	8·8	22·8	26·3
Area under cotton "	9·9	18·3	25·0
Cattle (million head)	25·5	43·8	43·9
Sheep "	40·9	50·4	41·9
Swine "	26·8	45·1	38·7

In 1870 the United States held, it would thus appear, a population of

38,600,000, and grew an acre of maize for each unit of the population, and an acre of wheat for every two persons, and somewhat more than an acre of cotton for every four. At this period the surplus exported to other nations, it may be added, represented two-thirds of the cotton, rather more than one-fifth of the wheat, but less than one per cent. of the maize.

In 1885 the population had augmented to an estimated total of 56,000,000, or by 45 per cent. The area under the crops above quoted had meantime been extended in nearly twice this ratio. The United States exported still about two-thirds of the cotton grown; the wheat export was slightly greater in proportion to the product than before, or 26 per cent., while nearly 3 per cent of the maize crop found a market abroad.

The population of the States is now estimated to have risen to 76,000,000, or twice what it was thirty years ago, although the census has yet to say if this calculation has been realised. The cultivation of maize had meantime reached 82,000,000 acres, wheat was reported to cover 44,000,000 acres, and cotton 25,000,000 acres, while the foreign market received 65 per cent. of the cotton, 33 per cent. of the wheat, and now as much as 9 per cent. of the maize grown on these areas.

In none of these cases, it will be noted, has the area under crop failed to increase, but in all the rate of increase was distinctly slower in the second than in the first half of the period. If time sufficed to trace the annual course of movement between the contrasted dates, it might be well remembered that from 1871 onward to 1889, with only a single slight check in 1887, the growth of the maize acreage has been continuous. From 1889 to 1894 fluctuations were reported yearly, ending in the latter year at a total acreage no higher than that of 1880, but returning again in a single year, if the record can be trusted, to the highest point reached. The wheat acreage movement has been more irregular, and the latest figures are complicated by the admitted corrections which were made to an amount of 5,000,000 acres for too low previous estimates in 1897. Allowing for this, the regular upward movement of the wheat acreage was apparently checked in 1880, and has only begun again since 1898 under the stimulus of higher prices in that year.

In live stock the development would seem to have been arrested altogether between 1885 and the end of the century in the case of cattle, and turned into an absolute decline in the number of sheep and swine, although in the fifteen years before 1885 cattle had increased more than 71 per cent., swine 74 per cent., and sheep 25 per cent. As a matter of fact the maximum number of cattle was reached in 1892, when the numbers were 54,000,000, or ten millions more than at present, the stock of swine declining in a still greater ratio from the same year. and sheep declining and rising again in the separate periods between 1883 and 1889, and between 1893 and 1897. If the ratio under each head to population is considered, it would appear that the United States possessed 661 cattle for every 1,000 of her citizens in 1870. This was raised to 829 per 1,000 persons in 1885, while the ratio now has fallen again below the starting-point, or to 604 per 1,000 persons. Sheep have fallen in the thirty years from 1,060 in 1870 to 880, and now to 537 head only per 1,000 inhabitants. These remarkable changes are worthy of note in connection with the exports of living animals and animal products, which last have been maintained at a still higher level than before.

Turning to a country of nearly stationary population, provided for in the main from its own agricultural produce with only slight assistance from abroad, a like contrast for the beginning, the middle, and the end of the period under review will give roughly the results shown below. Here, although we are provided with an annual figure, the start has to be made after the Franco-German war with the data two years later, or in 1872. (For table see p. 832.)

Thus in France, where wheat-growing has always had such a predominance among the cereals, the area is neither increasing nor diminishing. The total of 17,000,000 acres falls, however, somewhat short of the provision of an acre to two persons,

which held good in the United States; but this is more than corrected by the higher average yield, which is nearly 5 bushels per acre greater in France than in America. Taking wheat and rye together, there are a million acres less of bread corn grown in France than there was when her slow-moving population was two millions smaller, or less than 58 acres to 100 persons now as against 60 acres to the 100 twenty-eight years ago.

France	1872	1885	1899
Population, in million persons . . .	36·1	38·2	38·5
Area under wheat, in million acres . .	17·1	17·2	17·1
Area under oats ,, ...	7·9	9·1	9·7
Area under rye ,, ...	4·7	4·1	3·6
Area in vineyards ,, ...	6·5	4·9	4·3 [1]
Cattle (million head)	11·3	13·1	13·4 [1]
Sheep ,, ...	24·6	22·6	21·3 [1]
Swine ,, ...	5·4	5·8	6·2 [1]

The changes which the last quarter of the nineteenth century has seen in the leading features of French agriculture may be easily summarised. The population of 1872 but little exceeded 36,000,000, that of 1885 reached 38,000,000, and the latest data only bring it up to little over 38,500,000. The wheat-growing area remains, it would appear, under all conditions practically at 17,000,000 acres, the only break to the general uniformity of the cultivation of this cereal (with which the returns include spelt) occurring in the season of 1891, when, under exceptional climatic conditions, only 14,000,000 acres were harvested.

There is one typical French agricultural product—wine—which has materially declined under circumstances which are well known. The vineyards of 1872, which were reported as covering 6,500,000 acres, are now returned as less by a third of that area, and covering 4,300,000 acres only.

In cattle a material growth up to 1885, but a very small increase since that year, is reported; while if sheep, as in all European countries, are fewer, the fall is less than in Germany, and it is most marked in the first half of the period. Swine in France have steadily increased. As regards the cattle, it may be noted that France had 313 cattle to each 1,000 of her people in 1872, 345 in 1885, and 352 per 1,000 now. Of sheep the number per 1,000 is 560, against 681 at the earlier date.

Treating a few of the distinctive points of our own agriculture in the same way at the beginning, middle, and end of the past thirty years, the statistics of the United Kingdom would give these results :—

United Kingdom	1870	1885	1899
Population, in million persons	31·2	36·0	40·7
Area under wheat, in million acres . . .	3·8	2·6	2·1
Area under oats ,, . .	4·4	4·3	4·1
Area under other corn crops ,, ...	3·6	3·1	2·6
Cattle (million head)	9·2	10·9	11·3
Sheep ,, ...	32·8	30·1	31·7
Swine ,, ...	3·7	3·7	4·0

Here the most striking contrast with France is in the growth of population. From being a country with 5,000,000 fewer inhabitants the United Kingdom is now one actually greater by 2,000,000 persons than is France. This is an increase of more than 30 per cent., while the surface under wheat has heavily fallen, the main loss occurring under circumstances which have been amply discussed between

[1] In 1898

1875 and 1895. With some revival, as in America, consequent on an improvement of price in recent years, the slight apparent decline I have shown in the cultivation of oats is in fact confined to Ireland, the area in Great Britain being greater than at the beginning of the period. The cattle stock of the United Kingdom is increased by some 23 per cent., and the swine by about 8 per cent., while our flocks of sheep have been maintained at a level far exceeding that of other European States, and distinctive in a peculiar manner of the agriculture of Great Britain, for they still represent, as it appears, on the average 400 sheep to every 1,000 acres of land, against 164 in France, 81 in Germany, 32 in Belgium, and 17 in the United States.

Passing to a comparison with another great country, which, like the United States, is a typical exporter of more than one form of agricultural produce, it may be asked how far the available statistics of Russia allow such information to be furnished. For the earliest of the three years contrasted the dates for the Russian empire are meagre and unsatisfactory. Poland must be excluded as blank in our statistics at that time, while as regards animals no figures at all would appear to have been made public for any of the last twelve years. With such qualifications as these, the available data for the nearest year in the larger crops stood as under:—

Russia in Europe (*ex* Poland)	1870	1885	1899
Population in million persons	65·7	81·7	94·2 [3]
Area of rye in million acres	66·4 [1]	64·6	63·4
Area of wheat ,,	28·7 [1]	28·9	38·0
Area of oats ,,	32·8 [1]	34·9	36·1
Area of other cereals in million acres	?	31·4	34·2
Cattle in million head	22·8	23·6 [2]	(24·6) [4]
Sheep ,,	48·1	46·7 [2]	(44·5) [4]
Swine ,,	9·1	9·4 [2]	(9·2) [4]

Thirty years ago the population of European Russia, *ex* Poland, would appear from such data as we possess to have been estimated in round numbers at under sixty-six million persons. It is given as somewhere about eighty-two millions in 1885, and according to the recent census it is ninety-four millions now. The bread corn of the country continues to be much more largely rye than wheat, and the area in the year 1872, for which statistics are available, occupied by the former crop was practically an acre to the person, or in all 66,400,000 acres, less than half an acre per inhabitant, or 29,000,000 acres, being under wheat. The combined surface devoted to these two bread grains together was thus 95,000,000 acres in the aggregate, or 145 acres to every 100 persons.

Fifteen years later, when the population was apparently greater by 16,000,000 persons, or 24 per cent., the statistics of rye acreage indicate 2,000,000 acres less than before, or 64,600,000 acres. The wheat acreage, if the official data be accepted, was little if at all in excess of the 1872 figure, the rye and wheat together roughly giving 115 acres to 100 persons. The suggestion of this decline, while the exports of both grains were maintained or extended, affords an opportunity for closer enquiry into the basis of the published returns which are received from that country.

But carrying the review of the official figures further, the very latest data for this section of the Russian territory would appear to indicate a yet further shrinkage in the acreage of rye, but accompanied now, as was apparently not the case until lately, by a considerable increase in land under wheat. The total of this cereal is now put as high as 38,000,000 acres, but the net available area of breadstuffs, although brought up to 101,000,000 acres, represents a still diminishing ratio to population, or 107 acres to every 100 persons. Moreover, as Russia must

[1] In 1872. [2] In 1883. [3] Census of 1897. [4] In 1888.

be regarded as growing both wheat and rye for export as well as consumption, the larger proportions of her acreage which is employed in feeding a non-Russian population deserve to be specially marked in this connection, when the low yields of both cereals are remembered.

Whether the foregoing figures do indeed represent the facts of each period is, I think, a worthy object of enquiry for some of our younger statisticians, and it is a problem one would like to see solved as regards this particular country before venturing on any too confident conclusion as to what is the real meaning of the changes of the past, and what may be the future position in regard to the growth of breadstuffs and the growth of population in the world as a whole.

Calculations, however, such as those just quoted cannot fail to remind the student how very different in productive power the 'acre' of wheat may be, and is, in different countries. Assuming that we take the existence of 38,000,000 acres as reported of wheat land in Russia in Europe (*ex* Poland) to be proved, a comparison of the estimated yields shows that such an area represents less than 12,000,000 acres of the productive power we are accustomed to in Great Britain. So, too, for the vast wheat area of the United States, it takes two and a third acres to produce what is now our average yield in this country. Three Indian or three Italian acres of wheat of the calibre now in use would in the same way be required to supply the number of bushels that a single acre of our soil in the climate we enjoy, and worked under the system of farming that we practise here, would in ordinary seasons produce. In other extensive areas of wheat-growing the yields, though greater than the above, are very considerably below our own, the Austrian, Hungarian, and French yields standing at 16, 17, and 18 bushels respectively, against the 30 bushels which is apparently the average yield of the last five years in the United Kingdom. Only when we come to very small total areas do we find instances where the average wheat yields approach or over any considerable periods exceed our own. When Denmark, for example, is referred to as reaching 42 bushels per acre in the season of 1896, it is not to be forgotten that only a minute area of selected land, in this case only 84,000 acres, is devoted to this cereal. Results realised on this small scale can hardly be spoken of as an average in contrast with those of countries where millions of acres are grown, and can usually be paralleled in some sections of the bigger country.

Nor should it be forgotten, if the agricultural position of one State be compared with another, how widely the conditions of different parts vary from the picture presented by the average figures credited to the State as a unit, and how often sections of one country differ more from each other agriculturally than from the country with which they are contrasted. Within the United Kingdom alone we are, or ought to be, familiar with essential local differences of this type, which have to be kept in mind. Even in respect of the relative density of population and the number of mouths to be sustained in a given area, it may be quite correct to describe every 1,000 acres in the United Kingdom as carrying on their surface on the average 519 persons, but it may be remembered with advantage that, considered geographically apart, Scotland, for example, is a country of but 220 persons, and Ireland of but 219, to the 1,000 acres of area.

Such a position suggests that it might be fair to draw our agricultural comparisons between Scotland or Ireland as units of area, and such a country as Denmark, where the population is 248 to the 1,000 acres. Thus one-third of the cereal area of England is still devoted to the growth of wheat, while Denmark has but 3 per cent. so occupied, thereby resembling Scotland or Ireland, where some 4 per cent. only of the corn is wheat. Similarly, on this population basis, Austria with 320 persons, or Switzerland with 311, to the 1,000 acres may be not inappropriately classed with Wales, where the density is 345. In particular an examination of the live stock maintained by each 1,000 acres of the surface in all these cases affords parallels and contrasts which are both interesting and instructive. (For table, see p. 835.)

Thus Wales bears easily the palm as regards the total stock of sheep carried, while Ireland, with a population practically bearing a similar ratio to that of

Scotland to her surface, has more than three times as dense a stock of cattle and more than eight times as many pigs, although not much more than half as many sheep to the 1,000 acres. Although beaten as regards the number of pigs maintained on a given area by Denmark and by Hungary, Ireland's cattle are more than twice as numerous relatively as those of France, where the population is not so very different in proportion to the soil.

Country	Per 1,000 Acres of Total Area			
	Persons	Cattle	Sheep	Swine
Ireland	219	217	207	61
Scotland	220	64	390	7
Hungary	232	85	102	92
Denmark	248	186	115	88
France	293	103	164	48
Switzerland	311	132	27	57
Austria	320	117	43	48
Wales	345	147	685	50

Among countries where the areas are still greater in proportion to the resident population it may not be without interest to group together—as regards their present density—persons, cattle, sheep, and swine.

Countries	Per 1,000 Acres of Total Area			
	Persons	Cattle	Sheep	Swine
New South Wales	7	10	221	1
New Zealand	11	18	294	3
Victoria	21	32	234	6
Norway	26	13[1]	18[1]	2[1]
United States	32	19	17	17
Sweden	49	25	13	8
Russia (*ex* Poland)	66	20[2]	36[2]	7[2]

Such figures serve to emphasise the vast difference between the flocks maintained in our Australasian colonies and the other countries in this group.

The animal wealth of England by herself, omitting the Celtic fringes above quoted, may be compared with a nearer competitor. Belgium has 893 persons to 1,000 acres, England 925; and Belgium has 195 head of cattle and 160 head of swine, but only 32 sheep, on an average area of this size in her little kingdom, against 144 cattle, 64 pigs, and as many as 488 sheep in England. Were the comparison to be made more closely yet, the cattle stock of Belgium agrees closely in point of density with, say, the particular division of our area comprising the north-western counties of England, which have 194 cattle to 1,000 acres, or considerably more than the great butter-exporting country of Denmark, and at least a very close approach to the 197 head per 1,000 acres which are to be found in the fat pastures of the Netherlands.

These limited comparisons on single points of agricultural production in single countries do not, I know, satisfy the demands which are often made for world-wide surveys and comparisons on a larger scale. I confess I somewhat distrust the strength and due coherence of the statistical bricks on which these heroic conclusions are built up. It is most usual in corn trade journals, and the practice is sometimes followed in serious debate and reproduced in the year-books of the United States Government, to give a yearly

[1] In 1890. [2] In 1888.

picture of at least the world's wheat crop. For the close comparison of one season with another much must depend on the sufficiency of the weakest item in the account, and weakness is sure to creep in somewhere when crops are estimated on varying systems, at different dates, and on authorities of unequal value. The definitions adopted by one calculator as to the limits of the 'world' vary from those of another, and commercial estimates, as they are called, may be, at the discretion of the computer, substituted for or adopted in the absence of official data, so that the guesses at a single country's harvest may differ more widely from each other than would account for the total margin between one year's aggregate supply and another, to the confounding of satisfactory conclusions as to what is really happening. Last but not least of the obstacles to uniform grouping of harvests in complete years—ending as these years do at different periods—is the fact, not to be overlooked, that wheat harvests are being gathered somewhere in every month in twelve.

One is driven back then to the attempt to rest opinions on the growth of one form of culture or another on recorded acreage, rather than assumed production. Yet even here a good illustration of the difficulty of any extensive compilation may be found in the tentative memorandum Sir Robert Giffen put before the last Royal Commission on Agriculture as indicating, with many necessary reservations and qualifications, the relative movements of grain area, live stock, and population in the twenty years before 1893. Briefly, the earlier totals brought into conjunction for this purpose were made up, as regards the population figures taken to represent the starting-point of 1873, from the statistics of groups of countries and colonies at dates for the most part about 1871–3, but in some instances ranging back to 1866 and on to 1881, and aggregating 365,800,000 persons. Against these were set a total of 461,800,000 persons, enumerated, for the most part, about 1890–93, but in a few instances, where later data were wanting, going back to 1880–88, the growth of population between the totals being 26 per cent.

The acreage about 1873 and about 1893, contrasted with these figures, included wheat, rye, barley, and oats, but not maize—a larger crop than any of the last three. The countries contrasted were limited necessarily by the extent of information, and the list did not include all of which the population was accounted for, the increases per cent. being 28 per cent. in the case of oats, 19 per cent. in the case of wheat, 5 per cent. in the case of barley, with a decrease of 5 per cent. in rye. It should be observed, however, that the calculation as to the increase of wheat would have been much closer to that of population had not a very large area, nearly stationary in amount, been credited to India and Japan at both dates; the local population of these Asiatic countries being disregarded as, generally speaking, non-wheat-eating.

It was only as an outline pointing the direction in which enquiry might be useful that Sir Robert Giffen called attention to these figures, which, as he acknowledged, were of the roughest possible description, and rather suggestive of a closer enquiry, which should take account of the difference between the consumptive power of the countries aggregated, the varying productive power of nominally equal areas of surface, and the varying type of live stock maintained.

If the wheat acreage table, in the memorandum referred to, is examined in detail, a very effective picture of the difficulty of exact comparison as between any two given dates is incidentally presented. Out of twenty-four countries enumerated (including Canada and Australasia as units) a twenty or twenty-one years' comparison is only really effected in five cases—Russia, the United States, France, United Kingdom, and Australasia. In five other instances the period dealt with is only from seventeen to eighteen years; in three other cases only fourteen or fifteen years. In Canada, Egypt, and Denmark, the comparison will be found to be more limited still, and only to cover eleven or twelve years; while in the Argentine Republic, where the recent expansion of wheat-growing has been prominent, the available statistics allowed only of a comparison of two periods, no more than nine years apart. For seven other countries the wheat acreage was necessarily either omitted or inserted as presumably the same at both the earlier and the later date. Had the retrospect been confined to the cases where a twenty

or twenty-one years' comparison was possible—and these, after all, included the most important and typical wheat-growing communities—the increase would have stood, not at 19, but at 24 per cent., or scarcely below that of the growth of population generally. This result is reached without taking account of any South American figures, where the increase of area is relatively much greater, or of those of India, where the comparison is difficult and the acreage growing but slightly. But, further, it is to be remembered that if the comparison of the memorandum were to be continued up to 1899, instead of stopping at 1893, the figures would have shown that wheat-growing had apparently made a new start in the five important countries for which the long comparison was possible, as many million acres having been added in the past six years as in the whole preceding twenty—a result which may afford much occasion for suspending our final judgment and no little warning of the danger of single-year contrasts.

Since the above calculations were before the Commission there has been an extension of 10,000,000 acres in the official estimates of wheat areas in the United States, and 5,400,000 acres in Russia, while, although official details are still wanting beyond 1895 for Argentina, nearly 3,000,000 acres more were in that year accounted for in that republic; and there is an impression, apparently well founded, that by the present time the total may have reached 8,000,000 acres, or nearly five million acres more than the final figure in Sir Robert Giffen's calculation. If anything like 20,000,000 acres have thus been added to the wheat-growing surface of the globe in the last five or six years, which these further figures suggest, even if no correction be made for the Indian quota, there may be much less difference than was suggested in the memorandum between the growth of population and wheat-growing.

Without attempting in any way to controvert what was one of the lessons of the memorandum I have been examining, as to the tendency to increase the numbers of cattle at a ratio above that of population, it has also to be remembered that the apparent 37 per cent. increase there shown between 1873 and 1893 may have to be discounted by subsequent deductions in the United States, in Australasia, and at the Cape in recent years; while it is one of the problems I have never yet seen satisfactorily answered, why in almost all old countries except our own the diminution of the stock of sheep seems continuous and remarkable. I mention these matters only, however, to suggest the amount of uncertainty which must attend the efforts to arrive at conclusions, made even by the highest authorities, on the only data which exist. If there is, as I have shown, such uncertainty still in the facts on which a conclusion could be built as to the past history of the relative growth of live stock, or of cereal culture and the supply of bread-stuffs, how much greater must the difficulty be of those who attempt, on the basis of such data, to forecast the course of events for a generation yet to come! I confess I am not intrepid enough to follow some of the conjectures which have been hazarded on this point, and can only, in concluding this address, recur once more to the prime qualifications for safe statistical deductions with which I opened my remarks—redoubled caution in handling calculations, a very guarded use of data giving records of single and isolated years, and a wise reservation in any prophetic pictures of the future of agricultural production, whether of wheat or cotton, in meat or in wool, of the contingency, always present, of altered conditions which ever and anon in the past have altered and falsified the predictions of earlier observers.

The following Reports and Paper were read:—

1. *Report on Future Dealings in Raw Produce.*—See Reports, p. 421.

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2. *Report on State Monopolies in other Countries.*—See Reports, p. 436.

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3. *Population and Birth-rate, viewed from the historico-statistical standpoint.* *By* MARCUS RUBIN, *Director of the Royal Danish Bureau of Statistics.*

As is well known, it has become more common than formerly for historians to seek the help of statistics to support, as far as may be, with observations of groups, those scattered records which frequently give misleading results. A not unimportant part of the investigations undertaken, and of the tracts, &c., published by the author outside his official reports, have been concerned with historico-statistical investigations. One of the earliest of them—published in 1882—was concerned with the question of the number of the inhabitants of Copenhagen in the seventeenth century, an inquiry based on the records of *baptisms* in the church registers for that century. The paper offers an extension of the discussions of principle to which that inquiry gave rise.

The chief question to be answered is the following: Assuming that the number of baptisms at some period in the past can be ascertained for a town or a country, how can its population be deduced from that number? As a rule the registers give information only of baptisms, not of still-births. In general, at any rate in Denmark, children were baptised as soon as possible after birth, so that the numbers not baptised may rather be compared with the still-born of later times. Given the number of baptisms at some period in the past, this number must first be subjected to an addition before it can be compared with the record of births of recent times (living births and still-births). At the beginning of the present century the still-births were some 8 per cent. of those born alive. Thus to find the number of births of the earlier times at least 8 per cent. must be added to the number of baptisms. Having obtained this datum, what multiplier will yield the total of the population? This is dependent on whether people in former times married earlier than now; further, on whether marriages were more fruitful; and, finally, on whether the number of illegitimate births was greater.

It is quite clear that if, in comparison with the population, more children were born in preceding centuries than nowadays, the multiplier must be made less than would serve now to deduce population from births, and *vice versa.* Unfortunately, the old Danish church registers contain no record of the ages at marriage, but one may assume that people married earlier than at present, because such a course was in agreement with the needs and wishes of the time, whether considered from the point of view of State, of Church, or of public opinion.

I have secured information on this point from the records of a census of Denmark in the year 1787, which exist in the Danish Statistical Bureau, but have not been published hitherto. This census proves the following both for town and country:—In former times the well-to-do and independent section of the population married earlier than now, while the masses married later. This is a consequence of the fact that the labouring classes were not then free as now, but boarded in their master's house, and for this and other cognate reasons were obliged to delay marriage; whereas nowadays they need not wait; indeed they often find advantage in marrying young. The more well-to-do, on the other hand, married as soon as they could, since in old days people did not take our modern views in social matters, but regarded it as both the right and the duty of men (and of women) to marry as soon as law and custom made it possible. But, further, not merely did all marry as soon as they might, but they married as often as might be, *i.e.*, there were fewer widows and widowers than in our time, since none who could marry remained unmarried. To sum up, on the average the age of marriage was higher than in our time, because the masses were compelled to postpone marriage, but in spite of this the number of marriages was greater, partly because the well-to-do married earlier than now, partly because the masses married, almost without exception, as soon as they could, and, further, partly because the widowed remarried in far greater proportion than now. The statistical proof of the fact is given in the paper, where it is also shown that precisely the opposite happens nowadays to that which occurred formerly. Now the well-to-do marry late, the masses early.[1]

Although, on the average, marriages were later than now, yet the number

[1] See Table I.

of children to a marriage was at least as great as in our time. In our time the fertility of marriage is determined partly by physical, partly by social causes. Formerly the fertility of marriage was as great as nature permitted, just as marriage was undertaken as freely as the law and the economic development of the community permitted, not as nowadays, when people remain unmarried though not restrained by the fact of being unable to afford it. In spite of the marriages taking place later on the average, the fertility of marriage was not less than now. This position is established in the paper by means of statistics.

Finally comes the question of illegitimacy. A result of the masses being compelled to defer wedlock to a later age than now was that the number of illegitimate births was greater than in our time. This cannot be proved directly, but the paper shows, by the use of modern statistics, how the number of illegitimate children increases as the age of marriage among the masses increases. I am confident that the rule can be laid down for Denmark that in former times, both within and without the bonds of wedlock, more children were born relatively to the population than in our own time. The tendency towards a diminished birth-rate which can be shown for our time (and is demonstrated in the paper) did not exist of old. That the population did not increase was due, not to a small natality, but to a great mortality, as is also shown in the paper.

When the number of the baptised in former centuries is determined, a smaller factor must be used with which to multiply it, in order to deduce the population, than would be appropriate for our time. If the number of baptisms in former times be multiplied by 30, the numbers of the population will probably be determined to within 10 per cent. of excess or defect.

The following tables illustrate some of the more important facts to which allusion is made:—

TABLE I.—*Change in the Ratio of Civil Conditions at each Age-group in Denmark. 100 in each Age-group and for each of the Sexes.*

	Males			Females		
Ages	Unmarried	Married	Widowed	Unmarried	Married	Widowed
			(*a*) *Census of* 1787.			
20–40	56·6	42·6	0·8	44·9	53·0	2·1
40–60	8·8	86·9	4·3	8·0	77·6	14·4
60 and over	3·8	75·5	20·7	6·0	46·0	48·0
20 and over	33·1	62·2	4·7	26·6	60·1	13 3
			(*b*) *Census of* 1890.			
20–40	48·8	50·1	1·1	43·5	54·4	2·1
40–60	8·8	85·0	6·2	12·0	73·4	14·6
60 and over	6·4	67·0	26·8	9·6	42·2	48·2
20 and over	28·2	64·6	7·2	27·1	58·2	14·7

TABLE II.—*Change in Numbers in different Age-groups.*

	Of every 1,000 Males				Of every 1,000 Females			
Ages	1787	1801	1880	1890	1787	1801	1880	1890
0–20	408	409	440	454	401	403	416	423
20–60	512	503	471	450	506	498	482	469
60 and over	80	88	89	96	93	99	102	108
	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

FRIDAY, SEPTEMBER 7.

The following Papers were read:—

1. *Results of Experimental Work in Agriculture in Canada under Government Organisation. By* WILLIAM SAUNDERS, *LL.D., Director of Canadian Experimental Farms.*

For some years prior to 1884 agriculture in Canada was in a depressed condition, and during that year a Select Committee was appointed by the House of Commons to inquire into the best means of encouraging and developing the agricultural industries of Canada.

From the investigations of this Committee it was shown that farming in Canada was at that time in a very defective condition, that there was a lack of thorough tillage, that no sufficient measures were taken to maintain the fertility of the soil, that there was a want of knowledge in regard to rotation of crops, and of the selection of improved varieties of seed; that lack of information existed also in reference to many of the principles underlying the successful rearing of stock, the manufacture of dairy products, and the growing of fruit.

This Committee recommended that the Government establish an Experimental Farm where experiments might be carried on in connection with all branches of agriculture, horticulture, and arboriculture, and that the results of these experiments be published from time to time and disseminated freely among the farmers of the Dominion.

In 1886 an Act was passed by the Parliament of Canada authorising the Government to establish a Central Experimental Farm and four Branch Experimental Farms in different parts of the Dominion, and during the two years following these farms were established and set in operation.

The results of twelve years' experience have shown that these institutions have been highly beneficial to the farming community. Experimental research has been carried on along the lines prescribed by the Act by which these farms were established, and much information has been accumulated and distributed freely to the farmers of Canada in reports and bulletins. Benefits have thus been conferred on Canadian farmers in connection with all the more important farm crops, in the development of the stock and dairy industries, in the production of fruits, in the growing of trees for shelter and timber, and in the advancement of other branches of arboriculture.

Much attention has been given to experiments relating to the maintenance of the fertility of the land, to the best methods of cultivating the soil, to a proper rotation of crops, to the best time for sowing, and the selection of the best and most productive varieties for seed.

By freely spreading the information gained, supplemented by a liberal distribution of samples of the best and most productive cereals, crops have been improved, and the attention of farmers generally awakened to the importance of adopting such measures as will result in increased crops. The steady advancement which has taken place within recent years in Canada, and the increasing prosperity of agricultural industries, may in large measure be attributed to the useful work of these Experimental Farms established and maintained by the Government in different parts of Canada.

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2. *The Economic Possibilities of the Growth of Sugar Beet in England. By* A. D. HALL, *M.A., Principal of the South-Eastern Agricultural College, Wye.*

The sugar beet can be grown successfully in the south and east of England; the yield of sugar per acre is equal, if not superior, to the yield in other countries, where the industry is conducted on a large scale.

The economic question of the value of the industry is confused by bounties and

duties; it is therefore necessary to ascertain the possible profit of the crop at the price of sugar which prevails in the open British market. It is also desirable to find the value of the crop for consumption on the farm, pending the general establishment of factories to deal with the roots grown in each district.

In 1898 a series of trials was carried out on farms in various parts of the country; the average yield per acre was $15\frac{1}{2}$ tons of unwashed roots. This figure is probably too high, if roots with a high sugar content are grown; in the same year the average yield of six German estates, where an intensive system of cultivation is practised, was only 10·7 tons of washed roots per acre.

In 1898 six different kinds of sugar beet were grown upon the farm of the South-Eastern Agricultural College at Wye, Kent, the crop being managed in the same manner as the adjacent mangold break; the average yield per acre was 14 tons of unwashed roots, as against 29 tons of mangolds. The sugar content was highly satisfactory, the season being one of prolonged warmth: it is calculated that about $1\frac{3}{4}$ ton of sugar per acre could have been extracted, representing a gross return of 18*l.* 10*s.*

In several respects the crop is more expensive to grow than mangolds; manure and cultivation were found to cost 10*l.* 8*s.* per acre, to which rent, supervision, and all incidental charges must be added.

The roots grown were stored with the mangolds until spring, and given, together with cake and corn, to two selected lots of sheep, with the general result that each sheep consumed 63 lb. of sugar beet per week, against 146 lb. of mangolds, and that the increase in live weight was 30·6 per cent. with beet and 37·2 per cent. with mangolds. Recalculating on a basis of acreage required: ten-elevenths of an acre of sugar beet will provide the same amount of succulent food for sheep as an acre of mangolds, and will supply 38 sheep for 12 weeks; the sheep on mangolds will, however, make 293 lb. greater increase in live weight. The experiment showed that the beet forms an indifferent fodder for sheep.

Turning to the general question of the return to the farmer, the average price paid in 1898 in the six selected German cases mentioned above was 19*s.* 6*d.* per ton for roots delivered at the factory.

Assuming from the 1898 experiments an average English production of 14 tons of dressed roots per acre, the gross return to the farmer at the above price would be 13*l.* 13*s.* The cost of cartage from the factory to the farm must be taken into account: it is estimated that the 3,000 acres of sugar beet which Lawes and Gilbert specify as required to maintain a factory would mean an average distance from farm to factory of four miles, the cartage over which distance would cost about 30*s.* per acre for the 14-ton crop. When this is added to the cost of cultivation and an allowance made for rent, &c., there is no margin left for the farmer from the gross return of 13*l.* 13*s.* per acre set out above.

The 19*s.* 6*d.* per ton for roots is a price that is not possible in this country, the price payable for the raw material being dependent on the price of sugar. Taking similar grades of sugar, the return received by the German manufacturer was in January 1900 13*s.* per cwt., while the price in England was 11*s.* 3*d.* per cwt.; a difference of 35*s.* per ton of sugar. As $7\frac{1}{2}$ tons of beet are required to produce a ton of sugar, this difference in the price of the finished product is equivalent to a reduction of 4*s.* 8*d.* per ton in the price payable for roots.

The English figures, then, become: Average yield per acre, 14 tons; price at the factory, 14*s.* 10*d.* per ton; gross return to the farmer, 10*l.* 8*s.* per acre; against an expenditure which has been set at 11*l.* 18*s.* per acre, without including rent.

The success of the sugar beet industry depends upon several factors:—

(1) Cheap technical skill in the factories.
(2) A farming community working for smaller returns than prevail in Britain.
(3) A system of bounties and countervailing duties.

For further details see the *Journal* of the South-Eastern Agricultural College.

3. *The Economical Position of the Agricultural Labourer considered historically. By* FRANK P. WALKER, *B.Sc.*

1. Historical sketch of the chief phases in the history of agricultural labour, noting—

The Black Death, some of its results.
The depreciation of the coinage under Henry VIII. and its effects.
Poor relief and the settlement and allowance systems.
Competition the farmer has now to maintain (i.) in the market for labour with manufacturing operations, and (ii.) in the produce market with foreign supplies of food.

2. Three tables derived from replies to a form of questions attached to the paper and sent to certain farmers of my acquaintance. These show:—

(*a*) An increase in the amount of land laid down to permanent pasture.
(*b*) An increase in the wages paid for the several kinds of piecework concomitant with
(*c*) An increase in the weekly wages paid for all kinds of agricultural labour.

3. Notes on these replies, and conclusion.

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4. *Trade Fluctuations. By* JOHN B. C. KERSHAW, F.S.S.

The author stated that this subject had attracted in the past the attention of many minds, especially in times of commercial depression, and that the records of the Royal Statistical Society and of the Economic Section of the British Association proved that the members of these two learned bodies had not neglected to undertake their share in this investigation. But though some of the keenest minds in the realm of economic science had attempted to discover the laws which govern trade fluctuations, these phenomena of the industrial and financial world were still largely unexplained.

The currency, protection, free trade, war, famines, labour disputes, trade unionism, radical governments, and sun-spots had been advanced at one time or another as chief causes of the periodic depressions from which British trade suffers. Each of these explanations had, however, on examination proved unsatisfactory and insufficient to account for the fluctuations revealed when the trade figures over a long period of years were subjected to scrutiny in the light of the particular theory.

One theory, however, had seemed to the author worthy of further examination and inquiry, and for some months he had been collecting statistics bearing upon it.

The theory was that first advanced by Sir William Herschel, and supported in a qualified manner at a later date by Giffen,[1] Jevons,[2] and Binns.[3] Briefly summarised it was as follows:—

Normal trade between any two countries when reduced to its ultimate components was seen to be simply an exchange between the commodities which they produced. The countries of the world might be roughly classified as those in which the produce is chiefly that of the soil, or in which it is chiefly that of the hand and brain. The agricultural labourer and the skilled mechanic were therefore the representative human units of the two great divisions of employment, and all commerce was merely the exchange or barter of the products of their activities. The volume of trade must consequently be dependent upon the volume of crops if this theory of commerce be correct; and a series of bad harvests, using that term to cover every

[1] *Journal Royal Statistical Society*, vol. xlii. p. 36.
[2] *Currency and Finance*, chap. ix.
[3] *Journal Manchester Philosophical Society*, December 1894.

product of the soil, must sooner or later have their effect upon the trade in manufactured goods.

The trade statistics dealt with related to the value and volume of the exports of the United Kingdom for a period of forty-three years; and statistics relating to the total world crops of cotton, wheat, and sugar had been sought, with only partial success, for the same period.

These three agricultural products were selected because they are those upon the ample provision of which British industrial activity and prosperity appeared most largely to depend. The period 1856–1898 was selected because during these years British export trade had experienced most severe fluctuations, and also because the nearer one approached to the end of the century, the more reliable and complete were the statistics relating to trade and crops.

The figures collected by the author in the course of his inquiry, with full information as to their source, were given in an appendix to the paper; and for the purposes of comparison they had been thrown into diagrammatic form, which was distributed at the meeting.

The curve showing the *volume* of our export trade year by year since 1857 was marked by dips in 1860-62, 1873, 1876, 1885, 1891–93, and in 1897–98.

The curve showing the volume of the sugar crop of the world was marked by dips in 1861, 1864, 1868, 1872, 1875–77, 1880, 1886, 1888, 1896, and in 1898.

The curve showing the volume of the cotton crops of the four leading producing countries since 1870 was marked by dips in 1872–73, 1877–79, 1882, 1884–85, 1889, 1893, and in 1896.

The curve showing the volume of the wheat crops of the world since 1876 was marked by dips in 1879, 1883, 1885, 1888–89, and in 1895–97.

Finally a compounded curve showing the total crops of cotton, wheat, and sugar since 1876 was marked by dips in 1879, 1885, 1888–89, 1893, and in 1896–97.

In conclusion the author claimed that the theory of a connection between trade fluctuations and agricultural prosperity found support in the figures he had presented. Many causes no doubt combined to produce trade depressions, the mental mood of bankers and capitalists—so ably discussed by Mr. John Mills before the Manchester Philosophical Society in 1867—being one of these, and sudden change in foreign tariffs another. But the cause discussed in the author's paper was not less important, and when fuller statistics relating to wheat were available he hoped to continue his investigations.[1]

SATURDAY, SEPTEMBER 8.

The Section did not meet.

MONDAY, SEPTEMBER 10.

The following Papers were read:—

1. *Municipal Trading.* *By* ARTHUR PRIESTMAN.

The recent action of the London Chamber of Commerce and the Royal Commission.

The commercial world does not object when the trading helps them in their private undertakings. The increase and extent of municipal trading in U.S.A and other countries. Sir Henry Fowler's figures and the Blue-book returns. Comparison with capital invested in co-operative societies. Reasons urging still

[1] The Paper will be published in the *Journal* of the 'British Economic Association.'

further municipal enterprise: (*a*) health and housing; (*b*) milk supply; (*c*) telephones; (*d*) fire insurance; (*e*) savings banks; (*f*) drink; (*g*) combinations amongst traders.

Monopoly by combination of private traders in comparison with a municipal monopoly. 'General user' theory. Artificial raising of wages by municipal standard rate of wages. Can a city councillor undertake so many and increasing duties? Possibility of reintroduction of cottage industries by cheap municipal electric power supply. Conclusion.

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2. *Municipal Building for the Overcrowded. By* AUBERON HERBERT.

We can supply this want either by the system of free trade, which has done so much for us, or by enlarging once more the area of compulsion. The real question is then: Is compulsion a good or a bad thing? Undoubtedly it is easy and convenient; but does it not tend to bring serious evils with it—disagreement, careless and expensive management, corruption? does it not make children of us, spoiling the temper of compeller and compelled?

Let us see how the land lies. Looking round at Europe to-day we see a general failure of highly organised systems of compulsion. Writers of different schools complain that parliamentary institutions are breaking down. Almost everywhere minorities are in revolt against majorities. They obstruct, prevent discussion, and lock the machine. Once we hoped great things from the system of majorities and minorities. The sting was to be extracted from human disagreements, and we were to live side by side in a happy family. Unfortunately men have discovered that majorities are very keen to pursue their own particular interests; that to be in a minority means to lose all control, perhaps for many years, over one's own mind, body, and property, and that the ingenious precept that it is the duty of minorities to turn themselves into majorities, and so to possess the promised land, is rather like the nursery maxim—jam yesterday, jam to-morrow, but never to-day.

Why has the governing machine failed? Partly because men are not scrupulous enough to possess this power over each other, and spend the money of others on their own pet projects; partly because the game of politics accustoms us to the use of crooked weapons; partly because compulsion destroys competition and disfavours difference—'Progress is difference,' said Spencer, condensing a whole philosophy of life into that short sentence, and packing enough moral dynamite into it to upset a good many comfortable armchairs—and partly because the human race, keen to get its business done for it on such easy terms, and entirely forgetting the narrow limits of brain-power in these days of accumulated knowledge, has piled such a monstrous amount of work on the governing machines. The consequence is that Governments, overpowered by details and lost in a flood of useless paper-work, cannot control their own work; and the people cannot control their Governments, or even understand what is done in their name. The vastness, the multifarious character, the ever-extending range of what is undertaken, render ignorance compulsory on all of us, and we all, representatives and represented, go stumbling and blundering on together, attempting to do the impossible.

Just as it is with the big central machine, so it is with the smaller local machines. The same ambition to undertake everything and to play the part of earthly Providence, to be all-wise and all-directing; the same strife between parties, with the same handing over of the minds, the bodies, and the property of all to the victorious section—are producing the same results. What a chronicle of extravagance and corruption has met our eyes in many cities of other countries! what violent partisanship in the Paris and Vienna of the present hour! what organised illegality in New York! what desperate remedies in the suspensions of the right to govern themselves in the cities of America!

What is the remedy? Let our municipal bodies develop a voluntaryist side to their work. Instead of always compelling, let them sometimes *persuade* us to help them in some of their many duties. In this very matter let them appeal to us to

form building companies, with shares placed at a low amount, so that all may join. We cannot go on for ever slipping and sliding against our will into Socialism; we must learn to meet great wants in better fashion—the fashion of men who are not compelled. Then the new wants of civilisation will prove to be our best educators—developing energy and friendliness, and the power to work together. So long as we satisfy every new want by the easy and idle methods of compulsion, we learn nothing, for compulsion leaves all faculties undeveloped and only deepens the causes of strife.

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3. *Recent Changes affecting the Legal and Financial Position of Local Authorities in England. By* F. W. Hirst, *B.A.*

Changes in our Local Government Law may be produced in four distinct ways:—

1. By Act of Parliament, private or public.
2. By decisions of the Courts, *i.e.* changes of interpretation.
3. By orders and regulations.
4. By bye-laws.

With regard to the third heading it may be pointed out that there are drawbacks as well as advantages in connection with the central control exercised by departments like the Local Government Board, Home Office, and Board of Trade over the Local Authorities. The system of auditors is a good example of a form of administrative control which is wholly advantageous. But other forms of control involve administrative law, and both Parliament and the Courts are justly jealous of interference by bureaucratic boards which sit in London with the free play of representative local councils. In the case of Kreese *v.* Johnson, the late Lord Chief Justice held that Justices should be slow to invalidate a bye-law made by a local representative body. On the other hand the Private Street Works Act of 1892 substitutes Magistrates for the Local Government Board in appeals against apportionment.

Perhaps the development of Local Government by judicial decisions has been most marked of late years in the spheres of rating and drainage law. In the first, the recent case of Cartwright *v.* Sculcoates Union deserves particular attention. It follows, I think, from the important decision of the House of Lords in that case that the rent of a tied public-house is legally worthless as evidence of its rateable value, and that evidence of the business actually done on the premises not only may be, but ought, in such cases, to be obtained.

As regards public bill legislation there is no more interesting study than the rules by which Parliamentary Committees are, or ought to be, guided in dealing with applications for borough extension. This is a subject well understood and practised by Bradford, which is also a pioneer municipality in consolidating rating areas and placing the levying and collection of rates under the control of the Urban Authority—a reform much to be desired in the interests of good government and public economy. Another kindred subject is the extension of municipal industry by Private Acts. Lastly, it may be well to pass in review some of the more important measures which have been placed on the Statute-book during the last ten years, including, besides those already mentioned, the Light Railways Act of 1897, the Highways and Locomotives Amendment Act of 1898, the Isolation Hospitals Act of 1893, the Parish Councils Act of 1894, the Agricultural Rates Act of 1896, and the London Government Act of 1899.

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4. *The Local Incidence of Disease in Bradford: a Comparison between the Rates and Causes of Mortality in Bradford and those of England generally. By* A. Rabagliati, *M.D.*

The period dealt with is from 1874, when a Medical Officer of Health was appointed in Bradford, to 1895. The woollen industry as a whole not unhealthy, al-

though, in some details, as 'gassing' and the large amount of moisture present in the air in some of the dyeing processes, it might be improved. The birth-rate in Bradford exceedingly low. This largely accounts for a low death-rate and a low zymotic death-rate. The Bradford marriage-rate exceedingly low, and yet infant mortality very high; an unsatisfactory combination. Connection between the state of trade and the marriage-rate. Why the zymotic death-rate has not diminished in the last ten years. Has any part of the causes of zymotic disease been overlooked? Why has influenza come apparently to stay? Increase in cancer. Diminution in consumption. Comparison of mortality in Bradford from convulsions, diarrhœa, and the respiratory diseases, with that of England generally. General conclusions.

TUESDAY, SEPTEMBER 11.

The following Papers were read:—

1. *American Currency Difficulties in the Eighteenth Century.* *By* W. CUNNINGHAM, *D.D.*

To many Englishmen it is a matter of surprise that currency questions should be such prominent political issues in the United States at the present time, and it is instructive to remember that debates about the circulating medium were as common there in the eighteenth century as they are to-day. There has always been, as it seems, a considerable body of colonists or citizens who have believed that existing monetary conditions had been devised in the interest of some particular class, and that it was right and fair to manipulate the currency so that it should be more favourable to the interests of their own class or district. These efforts have generally resulted in depreciation of some kind.

1. The American Colonies in the seventeenth and eighteenth centuries had practically no coinage of their own, and there was great difficulty in maintaining the right standard of weight among the Spanish coins which formed the ordinary currency. The clipping and sweating of the coin was very common, and was even connived at by the authorities. In 1782, when Congress obtained a loan from France, it seemed absurd to let the heavy coins get into circulation, and Mr. Timothy Pickering was ordered, much against his will, to get 'a pair of good shears, a couple of punches, and a leaden anvil' for the work. If he had difficulty in the business he was referred to the Paymaster-General of the Forces, who was supposed to know all about it.

2. There have of course been various examples of the depreciation of the currency by the over-issue of paper in Massachusetts in 1740, in 1779, when a suit of clothes cost $2,000 in Continental paper, and in 1786, when attempts to circulate the bills of Massachusetts, Rhode Island, and New Jersey gave rise to much trouble.

3. There were few facilities for mining in America, and the issue of debased coin was impracticable; but the separate colonies, both on the mainland and the islands, had recourse to the expedient of raising the rating at which the coins in circulation should be accepted, so as to give each piece of money a greater nominal value, and temporarily at least a greater purchasing power. This can apparently be practised with success in a country where business is practically done by barter, or with commodity money, or where prices are the subject of authoritative assessment. All these conditions were largely present in the colonies in the seventeenth and eighteenth centuries. The object of a colony in enhancing the coinage and thus lowering all prices, was to attract silver from its neighbours, so that there might be more currency within its own area, and some relief from the inconveniences of barter. In 1698 Pieces of Eight were suddenly raised in Pennsylvania from six shillings to pass for seven shillings and eightpence. This involved a loss of nearly 30 per cent. on the tobacco duty when the cost of collection was defrayed. The variations were frequent and considerable, and were said to be due to 'the contrivance of some designing men in those countries who engross it when at the

lowest, and so make merchandise of it and export it into foreign parts.' At all events it gave rise to a sort of currency war between the colonies, each trying to draw away the circulating medium from others to itself. Thus about 1740 Virginia was attracting money from Maryland, and in 1798 the West Indian Islands set about establishing what Mr. Chalmers calls 'retaliatory ratings' against each other on a considerable scale.

It would be interesting to follow out the probable results of this method of manipulating the currency; immediately they would be precisely opposite to the consequences of debasing the issues from the mint. Debasing the coinage means a rise of prices; enhancing the coin is a lowering of prices all round; it does not increase the quantity of money in circulation; and while debasing the currency renders the exchanges unfavourable, the object of enhancing the coin is to attract bullion to the country. In so far as quantities of bullion were secured, there would of course be subsequent readjustments, but the immediate results would be very different from those of debasing the currency, except in one particular. Both methods of manipulating the currency would mean that creditors must accept smaller quantities of silver in satisfaction for existing debts.

This last does not appear to have been the motive of the Governments at the time; they seem to have been actuated by a reasonable desire to attract currency or prevent a drain of coinage, and to have pursued their aim by a method of very questionable honesty, but well calculated, under the circumstances, to attain the wished-for result. The conditions under which 'enhancing the coinage' can be successfully practised so as to influence internal prices are unlikely to recur in the business communities of the world; and there is little motive to have recourse to it, since it yields no immediate gain to a Government; but there is at least a scientific interest in noting how this method of manipulating the currency worked in a state of business relations with which many of us are unfamiliar.

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2. *Some Economic Consequences of the South African War. By* L. L. PRICE.

There is a tendency to attach an unreal importance to divisions of time like those parting one century from another; but the end of the nineteenth century is accompanied by a series of remarkable events. At the beginning of the century England was engaged in the Great War with Napoleon, which, in addition to direct influence on the finances of the country, postponed the progress of fiscal reform, caused the suspension of cash payments, assisted the alarming growth of pauperism, aggravated the evils of the early Factory System, and was followed by prolonged depression. The South African War, with which we have been occupied at the close of the century, is not, so far as its direct financial consequences are concerned, an economic event of the same magnitude. War is indeed more costly now, but the duration of the war with the Boers will bear no comparison with the twenty years of the Napoleonic contest. It may occasion a considerable permanent increase in military expenditure; but the sums involved in the two cases, taken absolutely, are very different, and, measured by the material resources of the nation, the earlier figure was enormous, while the later is trifling. The increased military expenditure may be accounted, on a strict interpretation of the term, 'unproductive,' and the growing pressure of foreign competition in our own manufactures and trade, coupled with the increasing cost of obtaining the coal which is still the source of much motive power, and the large additions made to local and municipal indebtedness, may render it desirable to husband resources and avoid augmentation of the National Debt. The Transvaal, however, will bear part of the direct expenditure of the war, and, even when the indirect burden is brought into the account, the total weight may be described as inappreciable, contrasted with the strain imposed by the Great War. But some of the possible economic effects of the later contest deserve attention; for it has been a disturbing factor, which may supply the force needed to move the currents of action from a groove in which they had settled. Passing by some obvious immediate consequences to the labour market and to trade, three points demand especial notice.

(1) In the first place, the influence of an increased output from the mines of

the Rand should be seen in a rise of gold prices. This is difficult to bring to quantitative measure, and prediction may prove deceptive. Sir Robert Giffen foretold, in 1894, that the fall of gold prices was ended; but in 1897 he confessed that his expectations were not yet realised. By the present time, however, the evidence of index-numbers, such as that of Mr. Sauerbeck, seems to show a rise beyond any movement due to credit, in spite of the temporary cessation of supplies from the Transvaal. But past experience enjoins caution in any estimate. The percentage of increase in the output is at present much less than it was at the Australian and Californian discoveries in the middle of the century. Predictions made at that time, even by a competent scientific observer like Jevons, were disappointed; and, although the 'compensatory action' of the bimetallic mint at Paris, which then acted as a 'parachute' to break the fall in the value of gold, is now absent, yet the normal counteracting causes, such as the increased use of the metal in the currencies of the world (apart from any special new demands), the great growth of trade and industry, and the influence of credit, have become more powerful. A rise of gold prices may be expected; but it is impossible to fix the point which it will reach. Its consequences will be beneficial, and may assist in solving unsettled monetary questions.

(2) The aid rendered by the colonies to the mother country in the war is likely, in the second place, to increase the momentum behind the conception of an Imperial Zollverein. There are special difficulties attending a Customs Union of the British Empire, arising from the separate situation of its component parts, which have not presented themselves in the case of Germany or the United States. These difficulties may, or may not, be eventually overcome; but some general considerations, apposite to the question, may be submitted to a scientific gathering like the British Association. Such a Customs Union, while it may conceivably result in an increase of internal free trade within the limits of the Empire, must, in all likelihood, involve some differential treatment of foreign goods. It must, so far, infringe the principles of Free Trade strictly interpreted. Recent theoretical discussion, especially of the incidence of taxation, has weakened some arguments for Free Trade, but the practical difficulty of limiting your action to what you really intend, and the great advantage of an attitude of neutrality on the part of Government in matters of trade, have not been diminished by recent experience. Yet an economic sacrifice may be incurred to secure a political end, or a temporary loss may be risked in the hope of an ultimate gain. The economist will urge that the step should be taken knowingly, and that its consequences should be seen and realised. On this ground the more obvious and open action of bounties is to be preferred to the obscure indirect influence of import duties. Lastly, the economist, while noting the crude fallaciousness of not a little reasoning, may admit the weight of some arguments employed against Free Trade. He may reach the conclusion that the matter must be decided mainly on practical grounds, and that theory ends with opening men's eyes to the results of their action. A *non possumus* attitude towards a Customs Union is no longer possible.

(3) A third and last consequence of the South African War, which must be briefly noted, is its effect on Socialism. The unity of classes at home, which has resulted from common interest, is not favourable to class dissension. The increased military expenditure is calculated to prevent or delay the execution of costly social experiments, although Chancellors of the Exchequer, seeking to broaden the bases of revenue, may possibly, if improbably, give effect to some socialistic aspirations of mulcting 'unearned increments.' Yet it may be a sound instinct which draws a distinction between socialism and militarism.

Finally, it may be remarked that the consequences of the war thus noted are certainly not unimportant, if they may seem problematic.

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3. *Colonial Governments as Money-lenders.* *By* Hon. W. P. Reeves.

For many years high rates of interest have been almost as much complained of by farmers and graziers in Australia and New Zealand as in the Western States of

America. Forty years ago 15 per cent. was commonly paid in the year in interest and commissions by this class of borrowers. By 1893 this had fallen to from 6 to $8\frac{1}{2}$ per cent., but the prices of produce had fallen in proportion. In the years 1894–96, the Governments of four colonies—New Zealand, South Australia, Western Australia, and Victoria—established money-lending departments for making advances on mortgage to the smaller class of farmers. In this way over 4,000,000*l.* has already been lent out. Details are given in the paper of 3,600,000*l.*, of which about 2,200,000*l.* has been lent in New Zealand, 790,000*l.* in Victoria, 530,000*l.* in South Australia, and 100,000*l.* in Western Australia. About 450,000*l.* has already been repaid. The New Zealand Government raises its loan capital by issuing stock in London; the others by selling mortgage bonds from time to time locally. In Victoria, this capital has been obtained at 3 per cent. (from the State Savings Bank); in New Zealand it has cost $3\frac{3}{16}$ per cent., and in South Australia $3\frac{1}{2}$ per cent. The rates charged to farmers are in New Zealand 5 per cent.; in the Australian colonies $4\frac{1}{2}$ per cent. The fees charged by all the State lending offices are very low—lowest of all in South Australia. The management expenses, are, however, small also, and the lending would seem at present to have been done prudently. At any rate, balance-sheets to the end of June 1899 and March 1900 show no losses, while of arrears of interest there were none in New Zealand, and but a few hundreds in Australia. The lending is done by way of first mortgage on freehold, or on leasehold held from the Crown. The loans are devoted to improving settlers' holdings, or to paying off existing mortgages bearing a higher rate of interest. In Western Australia they are restricted to the former purpose; elsewhere more than half the money is applied to the latter. The highest sum which may be lent to one borrower is 3,000*l.* The proportion of loan to security must not exceed 60 per cent. of a freehold, or half the selling value in case of a lease. An interesting feature is the system of repayment of loans by instalment. Under this the borrower pays 6 or 7 per cent. annually, of which $4\frac{1}{2}$ or 5 represents interest, and the remainder goes to form a sinking fund to extinguish the debt. In New Zealand every loan must thus be repaid by seventy-three half-yearly instalments. The mortgagee may, however, hasten the process by depositing additional sums or paying off the whole principal whenever he chooses. In 1899 the Government of New South Wales followed the example of the neighbour colonies and passed an Advances to Settlers Act.

As an example of the effect of these Acts in reducing rates of interest, it may be remarked that in 1894 almost two-thirds of the money of registered mortgages in New Zealand bore from $6\frac{1}{2}$ per cent. upwards. In 1898 six-sevenths of the mortgage money was yielding less than $6\frac{1}{2}$ per cent.

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4. *Variations of Wages in some Co-partnership Workshops, with some Comparisons with Non-Co-operative Industries. By* ROBERT HALSTEAD, *Secretary of the Lancashire and Yorkshire Centre of the Labour Association.*

The difficulty of securing suitable data for the purpose of the paper was considerable, owing to the fact that the kind of information required was very local and very special. The officials of thirty-four co-operative productive societies furnished information respecting 4,012 co-operative workers with a total wage of 209,521*l.* for the year 1899. Fourteen societies sent replies, the total wages of which amounted for that year to 122,313*l.* The average increase of wages in these co-partnership workshops since 1891 was 9 per cent. Means for comparison with non-co-operative wages are available for 1899 only, which shows a result in favour of co-operation of 7 per cent. Co-operative workers also have two hours a week less than non-co-operative workers. The figures also reveal that a large number of co-partnership workers were connected with their own trade unions. Particulars were supplied by ten societies, in which 246 workers were concerned, and in which last year the total wages were 9,486*l.* These showed that the workers had wages in excess of non-co-operative ones in the same trade and district by 11 per cent.,

and that they worked one and a half hour a week less. Moreover, the loyalty of these workers to trade unionism was shown by a high percentage of them being members of their own trade and district branches.

Five co-partnership societies with a total number of workers of 501, and wages for 1899 of 23,557*l.*, show an average increase in wages of 17 per cent. since 1891; but there is no means of comparing this with the wages of non-co-operative workers.

With regard to the five remaining societies little more can be said than that they paid more than standard or trade union rate of wages in addition to a share of the profit, and that in some cases they worked fewer hours than non-co-operative concerns.

The returns also show that in nineteen cases concerned there was an average increase of 11 per cent. from 1891 to 1899, and that in fourteen cases there was an average difference in favour of co-operative as against non-co-operative wages of 9 per cent.

This result in favour of co-operation is argued to be due partly to the sources from which the facts are obtained, but mainly to the high relative efficiency of co-partnership industries. The causes of this efficiency are held to reside in the fact that co-partnership brings the workers to more points of contact with the profit-making aspect of an industry than ordinary forms of production. Workers in co-partnership concerns have a special incentive to obtain higher wages, because they share in profits in proportion to their wages, thus absorbing as much as possible of the results of the extra efficiency due to their special form of enterprise. The large proportion of the worker being trade unionist is held to increase in force, inducing co-partnership societies to take the lead in the matter of wages.

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5. *Labour Legislation for Women.* *By* MARGARET E. MACDONALD.

Certain fundamental differences between men and women engaged in industry affect the question of legal regulation.

(*a*) Physical differences, *e.g.*, young mothers need special protection from unhealthy conditions.

(*b*) Differences in economic position. Even those women who do not marry are influenced by the fact that marriage is an event which revolutionises the economic condition and the industrial outlook of the great majority of women. As the result, women have a lower standard of pay and work than men. In a large proportion of cases they only need their wages as pocket money, or at most only to keep themselves, and where they are the breadwinners of the family they are usually overburdened with household cares and unable to stand out for better conditions. They are comparatively unorganised, *e.g.*, only 116,016 women are returned as members of trade unions, and of these 106,470 are in the textile trades. They are less ready to complain than men; *e.g.*, in the Post Office women only get half, or less than half, as much pay as men for the same amount and quality of work; yet the Tweedmouth Commission, while devoting great attention to the grievances of the men, made no recommendations with regard to women, naïvely explaining that 'there is a general absence of complaint from them.'

The comparatively low standard of women's work and pay has an injurious effect upon men's labour wherever it comes into competition with it; *e.g.*, the introduction of light machinery is constantly made the excuse for substituting women for men workers at lower rates. By setting a legal standard the State compensates to some extent for the lack of organisation and of a high standard amongst the women.

We have experience of labour legislation for women in certain classes of employment from 1842 onwards. By comparing the conditions of workers in these trades before and after regulation, and also comparing their conditions at the present time in regulated and unregulated trades, we find that in regulated trades:

(1) Sanitary conditions have improved relatively.
(2) Wages have risen relatively.
(3) The number of women employed have increased relatively.
(4) Organisation amongst the workers is more general.

This study encourages the further extension of legal regulation. In discussing the details of fresh legislation the following points are to be considered:—

(1) Classes of workers at present unregulated, or very partially regulated, *e.g.*, home-workers, shop-assistants, laundry workers, clerks, &c.[1]
(2) Matters for legislation—*e.g.*, hours of work, sanitation, dangerous processes, wages.
(3) Administration, central *v.* local authorities, women inspectors.
(4) Codification of present law, accompanied by differentiation to meet special requirements of special trades.

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6. *The Treatment of the Tramp and the Loafer.* *By* William Harbutt Dawson.

No time can be more fitting than the present for filling up an important gap in our penal system and for introducing a reform which became a logical and social necessity when the Poor Law was placed on its existing basis. The time has come for transferring the habitual vagrant and the loafer generally from the province of the Poor Law to that of the Penal Law. To the former they do not in any sense belong. The failure of centuries of reformers and legislatures to make the slightest impression upon the tramp population is largely due to the persistent mistake of treating his case as coming under the law of public charity. What society is bound to do, as far as possible, is to exterminate the social parasite of every kind. His existence is a positive injury to the State in every way. He robs the State not only of the industry which he owes it, but he consumes the produce of other people's labour and renders it nugatory, abstracting from the wealth of society without adding to it. His example scandalises honest workers; he is a standing menace to public peace and safety; and for society to tolerate him is not merely to condone injury done to itself, but absolutely to place a premium upon social treason of the most insidious and most vicious kind. Think what we do for the professional idlers! Take the urban loafer. While honest men are working we give him the free run of our thoroughfares and set apart for him the best of our street corners. Should he be a vagrant loafer we make it possible for him to travel through England from the Tweed to the Channel without doing one hour's serious work, save for the labour tests which are imposed by some—and only some—of the workhouses at which he may call. Who should wonder that our past indulgent treatment of the vagrant has had the effect of perpetuating and multiplying this class of social parasite? The dictum of wise Sir Matthew Hale is still irrefutably true: 'A man that has been bred up in the trade of begging will never, unless compelled, fall to industry.' But that is not the whole of the truth. Every one of these men creates imitators. On the highways he is a walking advertisement of the advantages of idleness, while in the model lodging-house, or wherever else the workhouse-shunning tramp seeks nightly shelter, he acts the part of recruiting sergeant for the great army of sloth and vice. What we should do, and shall have to do sooner or later, is to collect the tramps from the four winds of heaven and try to discipline the idleness out of their natures. For it is not, in the main at any rate, a dangerous criminal class with which we have here to do, but for the most part the weak and aimless characters whose great need is the moral tonic of discipline and compulsion. No faith should be placed in any cobbling of the existing Poor Law. No doubt a good deal more could be done to discourage vagrancy if the separate cell system were made universal, and if taskwork were rationally imposed; in a word, if the régime of the casual ward were made sufficiently rigorous to be deterrent, and

[1] See *Factory Inspector's Report*, 1899, p. 254.

if such rigorous action were made uniform throughout the country; and finally if magistrates more consistently enforced the laws against begging, sleeping out, and similar tramp offences. But this would only be a temporary makeshift, and the true remedy is to hand these parasites over to the Penal Law. In the first place, vagrancy and loafing generally should be made indictable offences. The right of free migration in the case of the destitute should be restricted to the extent of making it dependent on police permission to travel in search of work, after the principle of the police pedlar's licence. But, further, the casual ward must be abolished. This might seem a strong measure, but it is really the fulcrum on which the lever of reformation must rest. If loafing is to be regarded as an offence to be punished, instead of an innocent weakness to be humoured, the loafer's free lodging-house must disappear. The casual ward is entirely incompatible with the laws which already exist for the repression of vagrancy. It is illegal to beg; it is illegal to wander about without means of subsistence; but there is no habitual vagrant living who is not guilty of this compound fracture of the law, and few who have not been punished for it. Nevertheless, we wink at these misdemeanours, and in housing 10,000 vagrants every night in the casual wards—which, of course, is but a fraction of the total highway population—we offer direct encouragement to known law-breakers to persist in breaking the law. It would, of course, be necessary to meet the case of genuine seekers of work, and we should meet it considerately and indulgently. They would be expected to legitimise themselves by means of a police or properly attested private certificate, asserting their *bona fides* and destination, and this labour passport should secure the free right of lodging and food on the way. For them housing might be found in proper quarters, the workhouse, or any decent house of call, or in night shelters such as exist in Germany and Switzerland. But the crucial point is, How to deal with the vagrants and loafers who do not abandon their idle ways and seek work? After a first warning these should be detained—for a period sufficiently long for disciplinary purposes—in correctional institutions; the hardened cases in penitentiaries to be specially provided for in existing houses of correction whose régime should be modified to their needs, and the more hopeful ones in some form of labour colony which, besides receiving vagrants who had passed under magisterial jurisdiction, should also, as in Germany, Holland, and Switzerland, offer a temporary home to work-seekers of all kinds. It might be said that that was to admit the principle of the right to work. Even if that were so, the right to work is an infinitely better and wiser and safer principle to concede to the masses than the right to be idle. Early English laws really proposed in a crude fashion this very treatment of habitual vagrants and idlers, and Germany and Switzerland—the one a conservative and the other a democratic country—are treating the problem on these lines.

WEDNESDAY, SEPTEMBER 12.

The following Papers were read:—

1. *The Relation between Spinners and Piecers in the Cotton Industry.* *By* S. J. Chapman, *M.A.*

When spinning first became a separate industry for men at the beginning of this century the spinners successfully enforced apprenticeship rules; and even after the 'mules' and 'jennies' became longer, carrying more spindles—especially after power was used for driving the carriage backwards and forwards—and when consequently more piecers were required on some 'wheels,' the old apprenticeship rules were still enforced, and a distinction was drawn between those piecers who were 'learners' and those who were not. When, however, it became the rule to have on each machine piecers who were not learners, and when, moreover, improved machinery was rendering the learning of spinning an easy task, the distinc-

tion between piecers and 'learners' broke down, and the apprenticeship rules could no longer be maintained. Then the spinners adopted a new policy. They merely insisted on their existing large share of the total wage paid on the 'mules,' opposed all increases in piecers' wages, which they knew would be at their expense, and limited the quantity of machinery to each spinner. The result is that there are to-day from two to three times as many piecers as spinners, and that a great number of the former have been for years as fully qualified as the latter, though they receive at most only about half a spinner's wage. Both masters and piecers have attempted to do away with this arrangement, which is by no means economical, and which benefits only existing spinners at the expense of the piecers and all future workers in the industry. But the opposition of the piecers is weak because they are badly paid, and are ever hoping to become soon highly paid spinners or something else; and, on the whole, the men have been successful in resisting the masters' attempts to introduce the 'joining,' 'doffing,' and 'apprenticeship' systems, and the 'coupling of wheels' (double- and treble-decking), which were all directed against the existing arrangement of hands on the 'mules.'

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2. *Indian Guaranteed Railways; an Illustration of* Laisser Faire *Theory and Practice. By* Ethel R. Faraday, *M.A.*

The dogmatic rigidity of the *laisser faire* school, and their refusal to recognise the principle of development in economics, have produced the characteristic weaknesses of their policy, its carelessness of detail, its sacrifice of actual to nominal freedom, its neglect to provide for future possibilities, and its attempt to apply the same reasoning to different circumstances; all of which are illustrated in the later history of the Indian guaranteed railways. The guarantee system, in origin a purely practical expedient, had outlived its utility before it was revived by the English Government of 1868–74, apparently as being preferable, from the *laisser faire* point of view, to the direct State ownership which was considered by Lord Lawrence, as by Roscher, advisable in India. In the contracts renewed with three railways—the Great Indian Peninsula, Bombay, Baroda, and Central India, and Madras lines—it was agreed that the companies should receive interest at the guaranteed rate of 5 per cent. and half the surplus profits, no account being taken of deficits; that remittances to England should be converted at the rate of 1*s.* 10*d.* the rupee; and that calculations should be made on a half-yearly basis. The result was that the Indian Government bore all the loss of the unprofitable half-years and, after 1875, never received its full share of gain in the profitable ones, since, as the exchange value of the rupee fell below 1*s.* 10*d.*, the shareholders received a gradually increasing proportion of the surplus profits, while the contract obligation to pay interest at 5 per cent. deprived the State of advantage from cheaper money and improved credit, which would lately have enabled it to raise money at 2½ or 3 per cent. to pay off loans advanced at a higher rate of interest. On the three lines in question, taken together, the average proportion of earnings yearly remitted to England, 1892–7, was 99·70 per cent., and the net annual loss to Government amounted to 13,000,000*Rs.*, a tax imposed on the Indian public, for the benefit of the British shareholder, by that *laisser faire* school which objects to State railways as taxing one part of the community for the benefit of the other. Statistics showing the working expenses of railways formerly guaranteed, before and after their acquisition by the State, indicate that the guarantee system was uneconomical; but the fault is less with the companies than with the *laisser faire* English Government, which gave them the material advantages of liberty, and freed them from its responsibilities.

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3. *Price-changes in the Foreign Trade of France. By* Professor A. W. Flux, *M.A.*

Some twenty years ago, M. de Foville traced the variations of price-level in French trade by using for the years 1827 and 1847 to 1862 the values of the

trade of each year as ascertained and comparing it with the Official Value, which expressed its value at the prices fixed for the year 1827. From 1862 onwards these Official Values are not recorded, but in each year the trade is first valued at the prices of the preceding year, and, later, a revised valuation, at the prices of the year itself, is supplied. Thus the price-movements were traced from 1847 to 1878.[1] The paper continues the latter series of comparisons to 1898. Taking the price-level of 1862 as 100, the lowest level subsequently reached was in 1897, when imports reached 57·2 and exports 57·6. In 1898, neglecting fractions, the level of price for both imports and exports was 58. In the interval the fall of price-level for exports was almost unbroken, the elevations of 1864, 1872, 1880, and 1890 being comparatively slight. In the case of imports there was a considerable and sharp rise from 1869 to 1872, after which the course of the movement has been similar to that of exports, but so much more rapid has been the decline as to bring the figures for both sections of trade to approximately the same level in the last few years.

The piecing together of a record of price-movement before and after 1862 as ascertained by two different methods gives interest to the comparison of the measures of the movement from 1887 to 1896 by each of these two methods. The *Tableau Décennal* for 1887 to 1896 supplies a valuation of the trade of each year at 1896 prices. The two measures of price-movement give substantially the same results except in the years most removed from the year with which comparison is made. The fall of price is greater for exports, less for imports, from 1887 to 1896 as measured by direct evaluation of the trade of each year at the prices of 1896 than as measured by the index of price-movement previously obtained. The greatest difference shown falls short of 3 per cent. It is possible that, just as a divergence between the course of price-movement of imports and exports up to 1872 did not prevent the substantial identity of price-change in both over the period 1862 to 1898, so the divergence shown over a ten-year period, in the two measures of price-movement, is no proof that, could the same method have been used for tracing price-change from 1827 to 1898, instead of two methods linked together at the date of passing from one to the other, the indication of change of price-level over the whole period would have differed substantially from that actually obtained.

It is interesting to note that the difference of price-level in the early sixties and the late nineties as shown by Sauerbeck's Index Number is not far from the same as that ascertained by the methods used in the paper for French foreign trade.

[1] Cf. *Journal of the Royal Statistical Society*, December 1879.

SECTION G.—MECHANICAL SCIENCE.

PRESIDENT OF THE SECTION—Sir ALEXANDER BINNIE, M.Inst.C.E., F.G.S.

THURSDAY, SEPTEMBER 6.

The President delivered the following Address:—

LOOKING back at the Addresses of my many distinguished predecessors in this chair, I find that, devoting their attention as they have done either to the general progress of engineering knowledge or to those particular parts of it that have engaged their personal study, the possible field of observation has become somewhat circumscribed. Every one, I think, must by this time be fairly well acquainted with the progress made in our work during the present century or during the reign of Her Majesty the Queen.

But although this detailed examination of progressive advancement may appear at first sight to be exhausted, yet it may be not altogether unprofitable if we endeavour for a few minutes to consider how, and under what circumstances, that advancement has alone become possible.

Living as we do at the end of the nineteenth century, and surrounded as we have all of us been from our earliest years with a march of progress unequalled in the world's annals, we are apt to assume that the circumstances which surround us, the general attitude of the scientific mind, and our conception of nature and its phenomena, are things which come to us by nature as our birthright, forgetting that they are the result of thousands of years of work and thought among some of the greatest minds that the world has ever produced.

It may not therefore be displeasing to the audience which I see before me if in an imperfect way I attempt to lay before them some, at all events, of the salient facts which lead up to our present outlook on the scientific matters with which our profession deals.

We as civil engineers define our profession as being 'the art of directing the great sources of power in nature for the use and convenience of man.' Consequently our success or otherwise will depend on the estimate we may form of nature as a whole, and of those great sources of power which it places at our disposal. Undoubtedly in the history of the world there has never been a period when the study of nature has been so open and free from all prejudices of any kind whatever as it has been during the present century; nor, perhaps, with but few exceptions, has there ever been in any age or country a time when nature and her laws have been investigated with so pure and steadfast an aim after actual truth without the mind being prejudiced by authority or preconceived ideas derived from those great departments of human thought which deal more particularly with matters of faith, morals, and religion.

This equanimity of mind in which we now approach all subjects relating to science has not, I need hardly say, been the case in the past. Some persons may

ascribe it entirely to the inductive method introduced by Bacon, as opposed to the too exclusive confinement of the mind to the deductive systems of the older scholastic philosophy which preceded his time, and to which in a large measure he was undoubtedly instrumental in giving the death-blow. This view, however, is not altogether correct, for in the teaching of Socrates and Aristotle we find continued reference to the impor ance of inquiry, observation, and induction.

And in the cases of Hipparchus and Ptolemy in the best days of the Alexandrian school of astronomy we find the most laborious observations carried on for hundreds of years under circumstances and with instruments which we should now consider totally inadequate; and by their means discoveries were then made with an accuracy which surprises us; and from these discoveries conclusions were drawn which for more than a thousand years stood the test and satisfied the requirements of some of the most acute thinkers of the world.

We should, I think, in the first instance inquire how it came about that the great mental energies of philosophers of the ancient world failed to produce that fruit which we in later ages are gathering in such rich abundance.

To arrive at some idea on this question we must endeavour to picture to ourselves the inner consciousness of the great minds of antiquity when they first began to contemplate the circumstances by which they were surrounded, and were called upon by that inexorable and mysterious longing of the human mind to answer those great questions of the whence and the whither which are so strangely rooted in the hearts of all deep-thinking people.

To them were presented for the first time those great phenomena of nature by which we are always surrounded, many of these being of a character at once to charm and at other times to terrify the beholder. And in what I may call the childhood of the human mind, they, like children of a later age, were prone to ascribe to what they saw around them qualities and properties to which the phenomena in themselves had no relation.

What I may call the nascent deductive principle, so strong in all our minds, had given to it by these ancient philosophers the free play of fancy and imagination which led them to conclusions based on their own ideas and not upon the facts of unerring nature. Consequently we see in the early age of Greek thought the natural laws of the universe in smiling morn or darkening night, in raging sea or the thunderbolts of heaven, ascribed to the immediate action of benevolent or malevolent powers in the celestial world; and as a consequence the Greek mind from its earliest period became saturated with the beautiful conceptions of her poets, and following from this when philosophy first approached the subject, theories were broached and conclusions were adopted, many of them on an utterly erroneous basis.

Steeped as the Greek mind was in its lovely ideals of nature, it is not surprising to find that, when their philosophers began to formulate their theories, these deductions took the place of fact; and celestial observations, when they made them, as they undoubtedly did, were used, not for the purpose of illustrating the laws of nature as we interpret them, but as a means, partly religious and partly philosophical, in support of their preconceived ideas of the universe, the foundations of which, having been laid in poetry, became crystallised in the wonderful conceptions of the great men who directed their country's mind.

In looking, therefore, at nature in the earlier ages of scientific thought, we find that the standpoint from which everything was viewed was narrowed down to a universe constructed for man alone, the powers of which were governed by the caprice and whim of the great gods of Olympus, and yet even in this period we notice true opinions arising with regard to the structure of the universe. For instance, Pythagoras—and Aristarchus—conceived the idea that the sun was the centre of the universe, and that the planets revolved around him.

This correct deduction was to a large extent vitiated by bringing it into relation with another conception, that of harmonics.

Hence we find the true ideas of Pythagoras mixed up, and in a sense confused, by this theory of the harmony of the spheres.

And even when at a later period, more accurate observation gave the ancients

still better data on which to reason, they yet continued to ascribe, as the very names of the planets indicate, connections between them and the gods.

The outcome, however, of the teaching of the Greek schools, culminating as it did in the splendid work of the Alexandrian philosophers, resulted in the mistaken formula that the earth was the centre around which all the phenomena of nature were carried on.

It must not be imagined for one moment that Hipparchus and Ptolemy were not acute and accurate observers. They at an early period detected some of those inequalities in the moon's motion which require all the force of the gravitation theory to explain.

They defined, by patient observation, the irregular motions of the planets, sometimes progressing, sometimes retrograding, and with wonderful accuracy they were able to measure the precession of the equinoxes which carries the equinoctial points backwards along the line of the ecliptic.

They had a very clear conception of the rotundity of the earth, as we know from the fact that they made attempts to measure an arc of meridian.

All this wonderful mass of observation and discovery, when taking into consideration the imperfect means at their disposal, will ever remain throughout all ages one of the greatest monuments to perpetuate the fame of the men who produced it.

The question at once arises, How was it that with their wonderfully accurate observations and their perfect knowledge of the movements of the heavenly bodies they did not arrive at some of those revelations which later ages have brought to light?

It is difficult to answer this question with any degree of precision, but one can see clearly that their minds were governed, and the results of their inductions vitiated, by conceptions such as those of which I have above spoken.

These conceptions were that, seeing that the sun, moon, and planets appeared to revolve around the earth and return at different periods into closed orbits, therefore, as a circle was the most perfect of all figures, they must necessarily revolve in circular orbits, and that as celestial bodies this motion must be uniform

Consequently, to unite together the accurate observations that they had made of all the varying motions of the heavenly bodies, they had to invent circular orbits and smaller orbits carried by these in which the sun and planets revolved, and so gradually built up that wonderful and complex system, to which the name of Ptolemy is always attached, of cycles, epicycles, and deferents, by which in a most complicated manner they were able at length to reconcile their accurate observations with their preconceived idea of circular motion. The Ptolemaic system will always remain a wonderful monument to the skill of the observers and the acuteness of the thinkers in the ancient world.

Turning now to the domain of mechanics, with which were intimately bound up their ideas of geometry, we find, as our old friend Euclid has long since taught us, not only that they were among the most acute reasoners, but that they possessed logic, which, when applied to such conceptions as these, has remained after 2,000 years the text-book in our schools.

But in their estimate of the uses of geometry and the functions of the conic sections, the philosophers of old regarded them mainly as a species of intellectual athletics by which the mind was trained and perfected, and they believed that it was degradation to apply that knowledge to the affairs of mundane life.

In the case of Archimedes we see the master-mind grappling for the first time with some of the great problems of mass and of force, and solving to a large extent some of the principal problems placed before him.

But here also Greek notions of mass and of force were mixed up with others, which ascribe to them properties perfectly ideal, and it was considered, in the words of our great poet, that the application of these wonderful discoveries to the affairs of life was 'base mechanical.'

No doubt much of this was due to the fact that the teachings of the old Greeks were held to be exclusively the property of certain schools and academies, and that

the culture of the mind was the object in view. On the other hand, all the affairs of life connected with the mechanical arts were confined for the most part to a large section of the people who were held in slavery, and who, with but few exceptions, never rose to intellectual pursuits.

But, above all, as their ideas crystallised into the form of concrete theories nearly allied to many supernatural conceptions, these were gradually absorbed by the priesthood and mingled with the national faith, to differ from which, as in the case of Socrates, meant recantation or death.

Reviewing, therefore, the above impressions of the ancient world, we find the most accurate observations combined with the most fanciful theories, worked out with a logical and a mathematical skill which all the world admires, yet vitiated by conceptions or theories based on fanciful resemblances, and the whole gradually consolidated by priestcraft into a mass of superstitious dogma, to differ from which was to incur the odium of heresy.

We shall see as we proceed that this palsy of the mind was again repeated after a lapse of 1,500 years.

But even in the century which immediately preceded our era, we have indications that there were clear theories which had they been followed out to the full might have led to an earlier gathering in of the fruits of science.

At this point I may perhaps be permitted to read a few passages from the great Latin poet Lucretius, who in his sweet Pyrrhean verses attempts to lay before his beloved Memmius, the Roman soldier, the learning of the Greeks.

I shall use Munro's translation.

The entire six books are taken up by an attempt on the part of Lucretius to explain to Memmius the whole realm of nature, starting from the atomic standpoint of Democritus and Epicurus.

I should explain that in the following passages Lucretius calls the atoms the first-beginnings of things.

This poem was written in the first century before our era, and gives a good idea of the attitude of the Roman mind in its admiration of Greek philosophy, while at the same time attacking the gross superstition of the priests.

'When human life to view lay foully prostrate upon earth crushed down under the weight of religion, who showed her head from the quarters of heaven with hideous aspect lowering upon mortals, a man of Greece ventured first to lift up his mortal eyes to her face and first to withstand her to her face. Him neither story of gods nor thunderbolts nor heaven with threatening roar could quell: they only chafed the more the eager courage of his soul, filling him with desire to be the first to burst the fast bars of nature's portals. Therefore the living force of his soul gained the day: on he passed far beyond the flaming walls of the world and traversed throughout in mind and spirit the immeasurable universe; whence he returns a conqueror to tell us what can, what cannot come into being; in short on what principle each thing has its powers defined, its deep-set boundary mark. Therefore religion is put under foot and trampled upon in turn; us his victory brings level with heaven.' [1]

'This terror then and darkness of mind must be dispelled not by the rays of the sun and glittering shafts of day, but by the aspect and the law of nature; the warp of whose design we shall begin with this first principle, nothing is ever gotten out of nothing by divine power.' [2]

'We must admit therefore that nothing can come from nothing, since things require seed before they can severally be born and be brought out into the buxom fields of air.' [3]

'Moreover nature dissolves everything back into its first bodies and does not annihilate things.' [4]

'And yet all things are not on all sides jammed together and kept in by body: there is also void in things.[5]

'Time also exists not by itself, but simply from the things which happen the sense apprehends what has been done in time past, as well as what is present and

[1] Book I., p. 2. [2] *Ibid.* p. 4. [3] *Ibid.* p. 5. [4] *Ibid.* p. 6. [5] *Ibid.* p. 8.

what is to follow after. And we must admit that no one feels time by itself abstracted from the motion and calm rest of things.'[1]

Lucretius, speaking as in the following lines of atoms as the first-beginnings, appears to have the conception, not only of atoms, but also of molecules; for instance:—

'Bodies again are partly first-beginnings of things, partly those which are formed of a union of first-beginnings.'[2]

'But since I have proved above that nothing can be produced from nothing, and that what is begotten cannot be recalled to nothing, first-beginnings must be of an imperishable body, into which all things can be dissolved at their last hour, that there may be a supply of matter for the reproduction of things.'[3]

From the following quotations it will be seen that Lucretius had a very good idea of the struggle for existence and the survival of the fittest.

'That also which before was from the earth passes back into the earth, and that which was sent from the borders of ether is carried back and taken in again by the quarters of heaven.'[4]

'Thus one thing will never cease to rise out of another, and life is granted to none in fee-simple, to all in usufruct.'[5]

'And many races of living things must then have died out and been unable to beget and continue their breed. For in the case of all things which you see breathing the breath of life, either craft or courage or else speed has from the beginning of its existence protected and preserved each particular race. And there are many things which, recommended to us by their useful services, continue to exist consigned to our protection. In the first place the fierce breed of lions and the savage races their courage has protected, foxes their craft, and stags their proneness to flight. But light-sleeping dogs with faithful heart in breast and every kind which is born of the seed of beasts of burden, and at the same time the woolly flocks and the horned herds, are all consigned, Memmius, to the protection of man. For they have ever fled with eagerness from wild beasts, and have ensued peace and plenty of food obtained without their own labour, as we give it in requital of their useful services. But those to whom Nature has granted none of these qualities, so that they could neither live by their own means nor perform for us any useful service in return for which we should suffer their kind to feed and be safe under our protection, those, you are to know, would lie exposed as a prey and booty of others, hampered all in their own death-bringing shackles, until Nature brought that kind to utter destruction.'[6]

I must conclude my quotations from Lucretius with his splendid exordium to Memmius in the second book.

'Apply now, we entreat, your mind to true reason. For a new question struggles earnestly to gain your ears, a new aspect of things to display itself. But there is nothing so easy as not to be at first more difficult to believe than afterwards; and nothing too so great, so marvellous, that all do not gradually abate their admiration of it. Look up at the bright and unsullied hue of heaven and the stars which it holds within it, wandering all about, and the moon and the sun's light of dazzling brilliancy: if all these things were now for the first time, if I say they were now suddenly presented to mortals beyond all expectation, what could have been named that would be more marvellous than these things, or that nations beforehand would less venture to believe could be? nothing, methinks: so wondrous strange had been this sight. Yet how little, you know, wearied as all are to satiety with seeing, any one now cares to look up into heaven's glittering quarters! Cease therefore to be dismayed by the mere novelty and so to reject reason from your mind with loathing: weigh the questions rather with keen judgment, and if they seem to you to be true, surrender, or if they are a falsehood, gird yourself to the encounter. For since the sum of space is unlimited outside beyond these walls of the world, the mind seeks to apprehend what there is yonder there, to which the spirit ever yearns to look forward, and to which the mind's immission reaches in free and unembarrassed flight.'[7]

[1] Book I., p. 11. [2] *Ibid.* p. 12. [3] *Ibid.* p. 13. [4] Book II., p. 52.
[5] Book III., p. 80. [6] Book V., p. 136. [7] Book II., pp. 52, 53.

In the early centuries of our era, however, a great change was coming over the human mind. We have seen from the above quotations that, even before the advent of Christianity, thinking men were beginning to revolt against the superstition of the old mythology.

Soon after there arose the Neoplatonic school at Alexandria, which mixed up, in a way difficult to describe, beautiful conceptions of moral and religious training through astronomy and the sciences in an inexplicable tangle of pseudo-Greek philosophy.

At the same time there was gradually stealing over the minds of men an entirely new feeling, born of a new faith, which taught that things earthly and appertaining to the earth were of slight importance, and that all the splendid learning of the Greeks was but vain philosophy, and that the thoughts of man must be directed, not to the present, but to the future.

Among these conflicting ideas, there was intruded the outer barbaric power which knew nothing of science or of philosophy, but which, by its virile force and austere tenacity of moral worth, overran and conquered the Roman Empire.

These untutored peoples were soon attracted by the beautiful simplicity of the new religion, and were gradually absorbed into the Christian Church.

In the year A.D. 640 a serious blow was struck to advancing science, and for a thousand years we are parted from all the learning of the ancient world by the destruction of the Alexandrian Library by the Saracens.

Then followed for nearly a thousand years that period of intellectual torpor which we generally denominate 'the dark ages.' To a large extent natural science became unknown, the astronomy of the Greeks degenerated into astrology, and when occasional thinkers did inquire into nature's secrets, it took the form of alchemy, and a desire to discover the philosopher's stone, and the transmutation of metals. Mixed up with these were also a school of magicians, individuals who revelled in mysteries—always an indication of ignorant superstition.

During this period the ideas of the universe were taught from the books of Moses; even the learned lost all conception of the rotundity of the earth, and indeed we have treatises written to prove that we live on a flat world.

Of course, during the period I am speaking of there were some minds, in isolated cases, which still believed in the teaching of the Ptolemaic system. But the overruling authority of the Church crushed out all inquiry into the nature of things, deeming it sufficient that men should either remain ignorant, or devote their attention to a future existence.

At length, however, after the conquest of Constantinople, in 1453, there came a period when the literature of the ancient world again claimed attention, and the logic of Aristotle became the dominant factor in the teaching of the Church.

Another element was also contributing to the revival of the human intellect.

The Saracens, after their conquest of Alexandria, had preserved in the universities of Bagdad and Damascus much of the learning of the philosophers of the ancient world. This in the course of time followed their conquests along the northern coast of Africa, and was gradually grafted into the European mind by the teaching of the doctrines of the school at Salamanca; and it is to this channel, strange to say, that we are indebted for what we know of the tenets of Hipparchus and Ptolemy, as well as to many of the alchemistic sciences which they themselves assiduously cultivated.

Thus gradually we see dawning upon the benighted minds of the middle ages a revival of the learning of the ancient world.

The invention of printing and the lessons of the Reformation at once threw open the whole question to independent thought, and at the same time afforded a means of free interchange of opinions throughout the whole world.

About this same time the vexed question of the earth's rotundity was for ever set at rest by the discoveries of Columbus in 1492, and the circumnavigation of the globe in 1522.

I now approach a period when it becomes necessary to show, with somewhat more exactitude than that with which I have hitherto treated the subject, how

gradually there grew up in the minds of men those modern truths to which I have alluded in the opening passages of my remarks.

To attempt to do justice to this theme in the few minutes at my disposal would be indeed a vain endeavour; but for the purpose of showing the lines along which they ran, and to enable you to carry away with you the sequence of events to which I am about to allude, I have prepared a chronological chart.

This chart extends from the time of Edward VI., in 1550, to the present year. Horizontally it is divided, as you will notice, into years, and to the same scale vertically into years also.

Immediately below are marked off the reigns of the various English sovereigns, under which are recorded, against their proper dates, some of the principal political events of the period. At the top of the chart will also be found, against their appropriate dates, a record of some of the principal social events, voyages, discoveries, inventions, and other data which indicate the progress of science and the arts, as well as of those social events which mark the increase of civilisation and the growth of kindlier feelings in the human race. A few statistics are also given of population, the output of coal and iron, and the progress of railway development, to show how rapid has been the advance during the present century.

In the body of the chart are marked off by diagonal lines, commencing at their births and terminating at their deaths, the names of the great thinkers and workers, scientific and otherwise, who have done so much for the advancement of the human mind; and coming later in the field, and marked in red, are noted those engineers whose work alone became possible as the study of nature broadened out and bore fruit. Consequently, by running the eye vertically upwards at any particular period, it will at once be seen who were the great contemporaries of that period, to what predecessors they were indebted, and what was the state of science during their lifetime, and among what political events they carried on their work.

A very brief inspection of this chart will show that to no one man or country can be ascribed the sole merit of advancement.

Advancement depends on the knowledge we have inherited from our ancestors, and the opinions of our contemporaries acting on and reacting upon each other, and together forming what we may call the drift of opinion of any age or period which we may examine.

At the stage at which we have now arrived it is as well to conceive what must have been the feelings of men, especially of Englishmen, in the middle part of the sixteenth century. By the Reformation their minds had been opened to the exercise of private judgment, and there was presented before them a circumstance never before experienced, nor which can ever again appeal to the human mind.

By the discovery of the new world the earth space had been practically doubled. These two great factors, freedom of thought and the enlargement of the world, aided by printed books, produced fresh fruit in literature and science, and an enthusiasm, almost amounting to the romantic, which carried men on to enterprises of the most daring kind, and filled them with the confidence that a great and brilliant future was in store for the human race.

The poetry and literature of the Elizabethan period teem with these sentiments, and these feelings sank deep into the minds of thinking men when they contemplated more serious subjects.

Peter Ramus (1515–1572) attacked the Aristotelian philosophy.

Copernicus (1473–1543) revived the idea of Pythagoras and Aristarchus, that the sun, and not the earth, was the centre around which it revolved in company with the other planets. He, however, still retained the notion that they revolved in circles, and had, of course, to resort to epicycles, deferents, and the like, to account for their apparent irregular motions.

At a little later period, Tycho Brahe (1546–1601) was carrying on a series of astronomical observations of an accuracy never before attempted; and although he did not accept the Copernican theory, yet he so far began to lose faith in that of Ptolemy as to propound a theory of his own to reconcile his more accurate observations.

About the same time, William Gilbert (1540–1603) published his work on the

magnet, and Sir Francis Drake, led away by that enthusiasm of which I have already spoken, in his great voyage round the world added new glories to English navigation.

As conceptions more exact and observations more accurate were made, it became necessary in some way to shorten the laborious calculations previously carried on. Hence we get about this time the invention of logarithms by Napier of Merchiston.

But this evident advancement of the mind was opposed fiercely by the powers of the Church, resulting in the burning of Giordano Bruno at Venice, in the year 1600, for upholding the Copernican theory.

There now came upon the scene one of the greatest thinkers of our country, to whom all Englishmen, if not all Europeans, should feel the deepest gratitude, the great thinker, Francis Bacon, who, in his various works which he has left behind him, bequeathed to future ages that system of inductive philosophy which has done so much for the advancement of learning.

As you will remember, his first doctrine is that we must avoid the errors which are inherent in the human race, and which he classes under the four heads of 'Idols of the tribe,' 'Idols of the den,' 'Idols of the forum or market,' and 'Idols of the theatre.'

Having got rid of erroneous and preconceived opinions, he lays down rules of right thinking, afforded by scientific facts which have been invaluable in the investigation of science.

He does not touch upon religious and controversial subjects which engaged the attention of so large a proportion of his contemporaries, but directs the whole force of his philosophy to the acquisition of what he calls 'fruits,' that is to say, the pursuit of truth for its own sake.

And as Macaulay says of him, although he is best known by his essays, yet of his more philosophical works he remarks that 'they have moved the intellects which have moved the world.'

We now have to consider for a moment a name which should be highly honoured among all men of science, but especially among engineers, for to Galileo we are indebted for the first principles of mechanics. He invented the thermometer about 1602, and the telescope which bears his name in 1609.

In 1586 he composed his first essay on the hydrostatic balance, and his observations on the swinging of the great bronze lamp in the Cathedral of Pisa, as well as his experiments on the centre of gravity, and on falling bodies from the leaning tower, laid the foundation of the exact determination of some of our simplest mechanical conceptions.

His astronomical observations of the moon, his discovery of Jupiter's satellites in 1610, as well as the rings of Saturn and the phases of Venus, gave to the Copernican theory the basis of fact which was before wanting.

It is needless to say that Galileo advocated most strongly the theory of his predecessor Copernicus, and for the doctrines which he so taught he was brought before the Inquisition, imprisoned, and his latter days rendered miserable by the persecution of the Church.

Contemporary with Galileo was his illustrious correspondent Kepler, who in the most laborious manner, from the observations of Tycho Brahe and other accurate astronomers, gradually gave to the world those laws which bear his name, and fixed for all time the fact that the planets revolved around the sun, not in circular, but in elliptical orbits.

These teachings, assisted by the illustrious Gassendi, were gradually forming in the minds of men a somewhat more accurate idea of the universe in which we live.

We now come to one of those great minds, who, in the realm of philosophy, had a vast influence in turning the thoughts of men into direct channels. I allude to that distinguished Frenchman, René Descartes.

I do not propose to inquire into his axiom, 'I think, therefore I am;' into his conception of innate ideas, nor into his theory of vortices, but would merely point out what may be almost called his great discovery, namely, the application of

algebraical reasoning to geometrical conceptions and astronomical observations.

Of course his freedom of thought offended many, both the Jesuits, in whose school he had been educated, and the pastors of the Reformed Church, among whom he lived in Holland. And it is well known that he delayed to give to the world some of his best ideas owing to the way in which Galileo had been treated by the Church.

The English philosophical writer, Thomas Hobbes, by the publication of his work called 'The Leviathan,' was also educating the minds of Englishmen in the direction of sound knowledge.

It is interesting, however, to note that the new ideas had not as yet sunk deeply into the minds of the English people.

Shakespeare remarks: 'He that is giddy thinks the world turns round' ('Taming of the Shrew'). Bacon also never accepted the Copernican theory, and if we turn to the eighth book of 'Paradise Lost' we find that although Milton, who had visited Galileo in Italy, and who was well acquainted with the theory of Copernicus, founds his whole poem on a Ptolemaic basis, yet he was, apparently from the words which he puts into the mouth of the archangel Raphael, halting between two opinions.

We now have to note another of the experimental philosophers in Christian Huygens.

Up to his time, the means of making accurate observations in which time was concerned was a most difficult, nay almost an impossible, matter. By his introduction of the pendulum, as a regulator of clocks, he at once placed in the hands of men of science one of its most valuable instruments.

His work on the centre of oscillation and the cycloidal curve shows how deeply he worked out the theory.

His observations on double refraction, and his promulgation of the theory of an elastic ethereal medium in which the vibrations of light are carried on, place him in the forefront of the observers of his time.

The sagacious Hooke, Wren, Wallis, and Newton's great master Barrow, as well as the distinguished Boyle and the indefatigable Oldenburgh, were all carrying forward the work which distinguishes this period; and when we look back to those pleasant meetings at Wadham College, Oxford, during the Commonwealth we contemplate a body of men working for true science who were to be the founders of that Royal Society which has done so much for the advancement of science throughout the world.

The labours of all the great men of whom I have yet spoken were at this period gradually drawing together a vast mass of facts which required some common explanation. The rudiments of mechanical science were beginning to teach the truth as to the laws of falling and oscillating bodies.

The Ptolemaic system, with its complex theories, was gradually yielding to the accumulated evidence in favour of the Copernican system.

The erroneous idea of circular motion had yielded, as the fruit of Kepler's persevering work, to the law of elliptical orbits.

But yet the minds of many men were still directed by the idea that the planets were carried round the sun by some inherent force in themselves, and in the same very imperfect way they were beginning gradually to think that this force, be it what it might, acted in inverse ratio to the square of the distance.

Matters were in this state when there arose the greatest genius that the English race has yet produced, the retiring, the sensitive, and the devout Isaac Newton, who, acting like an electric spark in a mixed and chaotic mass of vapour, at once precipitated, as it were, the confusion, and brought to light, with a dazzling brilliancy, the gravitation theory, which not only accounted for all the difficulties which his contemporaries were struggling with, but at one bound elucidated those many and confusing motions of the heavenly bodies which had hitherto been the stumbling block of observers.

By his discoveries, for the first time an accurate scale was given to the universe, and in his statement that every particle of matter in the universe is attracted

directly as the mass, and inversely as the square of the distance, we have laid before the world once and for all time a sure and certain guide to all the phenomena of nature.

He reveals to us distances incomprehensible, and magnitudes which transcend the most fanciful ideas of his predecessors, and flowing from this we have established the important conclusion that as far as matter is concerned, whether in the case of our own planet, in the sun, in the mighty orbs of Jupiter and Saturn, or in the distant nebulæ and stellar masses, the whole is governed by exact law, and is not a fortuitous concourse of atoms, or the result of some unexplained and inexplicable vortex motion.

We may say of him in the words which I have above quoted from Lucretius, 'the living force of his soul gained the day: on he passed far beyond the flaming walls of the world and traversed throughout in mind and spirit the immeasurable universe; whence he returns a conqueror to tell us what can, what cannot come into being; in short on what principle each thing has its powers defined, its deep-set boundary mark.'

We must now turn to the contemplation of a great thinker who, although not a scientific man, has yet had the most profound influence in the direction of clear reasoning of perhaps any man in England since the time of Bacon. I allude to the illustrious John Locke, the friend of Newton, of Boyle, of Monmouth, of Somers, of Clarke, of Montagu, of Pembroke, and of Shaftesbury, admired alike by Horace Walpole and by Voltaire, and the trusted friend and councillor of William of Orange.

Intimately connected with the freedom of the press and the currency of this country, one of the first commissioners for trade and the colonies, he is principally distinguished by his charming essay on 'The Human Understanding.'

Putting aside the metaphysical conception of Descartes, he lays down the law that all our knowledge must be founded on two principles, experience of the outer world through our senses, which he calls 'sensation,' and the inner working of the mind on the experience so gained, which he calls 'reflection.'

To his clear and lucid English which appeals to every reader, taken in conjunction with the simple facts which he enunciates, the English nation is indebted for much of that common sense and freedom from fanciful speculation for which we are distinguished among the nations of the world.

At the end of the seventeenth century Boyle, Hooke, and many others of their illustrious contemporaries were, in the early days of the Royal Society, founding that school of physics and chemistry which, taking the place of the alchemy and the magic of the middle ages, was being gradually moulded into shape in accordance with true induction and in a scientific spirit. But little had yet been done in the study of the earth itself.

Pliny mentions the fact that fossil shells had been found; and Leonardo da Vinci, about the beginning of the sixteenth century, had argued that these fossils were the remains of extinct beings, and not *lusus naturæ* formed by the action of the stars on the plastic substance of the earth; nor, as taught by the Church, shells dropped from the hats of pilgrims on their way from the Holy Land.

And even at the end of the eighteenth century Johnson spoke, as it will be remembered, of people engaged in such a study as 'fossilists.'

We are indebted, however, for right thinking on truly scientific lines to Hutton, to Playfair, to Werner, and to Cuvier, who about the end of the eighteenth century began to formulate distinct and clear conceptions on the subject.

The rocks of which the earth's crust was composed were gradually being divided into aqueous, plutonic, and metamorphic.

It was clearly established that among the aqueous deposits the various strata contained fossils different both in kind and in species from those of living beings.

To our illustrious countryman William Smith we are indebted for the first geological map of Central and Northern England.

Controversies arose as to how the great succession of events which accurate inquiry was unfolding to our knowledge was produced: whether upheavals and depressions in the earth's crust were due to sudden cataclysms, dividing and

shutting off, as it were, each successive period from those which preceded or succeeded it; or whether, as some imagined, they were the result of the Noachian deluge.

And in the beginning of this century fierce discussions arose as to whether or not the whole tendency of these investigations was not intensely irreligious, as it appeared to be at variance with the account of the creation as given by Moses.

In 1830 to 1833, however, by the publication of his 'Principles of Geology, or the Modern Changes of the Earth and its Inhabitants,' Sir Charles Lyell, following on the lines laid down by Hutton and Playfair, in the most philosophic spirit proved beyond a doubt that all the great changes which geology disclosed were the outcome of the action of those forces of nature which we see around us, operating with greater or less energy throughout long ages.

Lyell did not attempt to theorise on how or why the remains of extinct animals and plants succeeded each other in the rocks, but he pointed out in the most precise manner that, whether we take the primary, the secondary, or the tertiary periods, the different series of organisms, of which we find the remains, were each distinctive of its particular zone; and that as we examine the tertiary strata their characteristics become more and more similar to the animals and plants which we see around us at the present day.

Newton had taught us that the sum of space throughout the universe is practically unlimited, and that the whole is governed by law and not caprice.

The teaching of geology has instructed us in a somewhat similar way that the time over which the present forces of nature that have tended to form the earth, as we now see it, have operated, is to be measured, not by 6,000 years, but by many millions of years.

I do not pretend to enter upon the vexed question of how many millions of years, but what I wish to direct your attention to is that, as astronomy teaches an almost infinite space, geology teaches not perhaps an infinite but a vastly extended period of operation almost beyond the grasp of the human mind.

I have spoken above of the action and interaction of the thoughts of our predecessors and our contemporaries in forming and originating new scientific conceptions in different periods.

A curious example of this is to be found in modern science.

Malthus published his essay on population in 1798, Sir Charles Lyell his 'Principles of Geology' in 1830 to 1833.

The great Charles Darwin has told us that it was by the study of these two books that he was first led to contemplate those changes in nature, and to amass that vast collection of scientific thought, which resulted in 'The Origin of Species,' published in 1859, coincidently corroborated by the illustrious Wallace.

The co-operation of these two great thinkers, the graceful way in which the younger gave place to the older observer, marks an advance in the kindlier feelings of contemporaneous scientific workers, in marked contrast to the virulent and often acrimonious controversies which characterised the period of Descartes and Newton.

I am not going to enter into a description of the Darwinian hypothesis, but it is sufficient to say that putting on one side for a moment the details with which it deals, the teaching of Darwin has produced during the last thirty years an entire revolution in our ideas, whether we look at them in literature or in science, by which we begin to understand how, in the long series of past ages, the various organisms which we find in the fossil state have passed gradually and almost imperceptibly from a lower to a higher state of organisation. And possibly in the teachings of our great countryman we see, for the first time, perhaps, in a somewhat dim and distant way, a scientific reason for the origin of those innate ideas which formed so large a portion of the teaching of that great Frenchman René Descartes.

And, again, we see in the teachings of science the reiterated lesson that nature works by slow degrees in an orderly and regular succession, ever advancing, ever improving, and not by spasmodic jerks; and the train of such ideas naturally leads the mind to the contemplation of a future more perfect and more beautiful in all that is good and true.

And in the words of Tennyson we may say—

> Yet I doubt not, through the ages one increasing purpose runs,
> And the thoughts of men are widened with the process of the suns.

It is not my object to trace the advance of science in all its branches down to the present time.

I have above indicated the general lines along which the human mind has advanced in laying the foundations of our modern views; but so intimately are we, as engineers, connected with all the sciences that I must just refer in the briefest manner to the development of chemical science as it grew out of the teaching of Aristotle and Galen, that there were four elements, to the acid and alkaline discoveries of Sylvius, through the teaching of Geoffrey and Stahl of the phlogistic theory.

We then have the discovery of oxygen by Priestley, and fixed air by Black and Cavendish, composition of water by Cavendish, Watt, and Lavoisier, followed by Davy and Dalton, the latter of whom formed our present conception of the atomic theory and the combination of the elements in their true proportions.

Through Davy, Faraday, and Tyndall we gradually arrive at our electro-chemical ideas of the present day.

We last year had so lucid an exposition from Professor Fleming, at Dover, of the march of progress in electrical science during the past century that it would be presumption on my part to attempt to recapitulate even the names which extend from William Gilbert, in the sixteenth century, down to the discoveries of Hertz of the present day. But I may be permitted to point out that from the time of Volta, Ampère, and Oersted the rapid progress which electrical science has made has been due in no small measure to the manner in which its experiments have been treated, on strictly mathematical lines, by the master minds of such men as Maxwell and Kelvin, until at last we arrive at the demonstration, long foretold, of the wave theory, which renders wireless telegraphy an accomplished fact.

Light to the engineer has at all times been of supreme importance, and on the chart we may scan the names of those who have advanced our scientific knowledge of it from Galileo, Descartes, Huygens, Gregory, Newton, up to Roemer who discovered its velocity, then Halley, Herschel, and the illustrious Thomas Young who revived and Fresnel who perfected the undulatory theory, until at last we come to those mysterious Fraunhofer lines, previously noticed by Wollaston, interpreted by Bunsen and Kirchhoff in 1860, and applied as an aid to chemistry in the analyses of terrestrial and celestial bodies.

In the theory of heat we have the experiments of Cavendish and Priestley investigated by Count Rumford, illustrated by Tyndall, and bearing fruit in Joule's mechanical equivalent.

Perhaps none of the allied sciences appears so distant from our own profession as that of physiology.

The discovery of Harvey gives us, however, a beautiful insight into animal mechanics; and the observations of Leeuwenhoek about the year 1700 first bring us into contact with those minute organisms which he discovered by means of the microscope, and which are now found to play so large a part in the economy of nature.

Up to within the last twenty years it was generally held that dead organic matter, animal and vegetable, could but, in the words of Shakespeare, 'lie in cold obstruction and rot,' this process being assisted, it was assumed, by chemical oxidation; and, until the researches of Pasteur and Koch, we were entirely ignorant of the fact that nature had at her command countless millions of organisms, always reducing the effete products of animal and vegetable life back into simpler elements.

The tendency of later years has clearly been, whether we look at the links which unite heat and work, chemistry with electricity and magnetism, and light with both, or physiology with chemistry, to obliterate those boundary lines which we have been accustomed to regard as fixed, and from the time of the publication

of Sir W. Grove's correlation of the physical forces in 1846 we have made continued advances in the same direction.

What the future may have in store for us we cannot imagine, but clearly if we compare the facts known at the commencement of the nineteenth century with those in our possession at the beginning of the twentieth century, we may look forward to a still richer harvest of what Bacon calls 'fruits.'

Looking back upon the facts that I have been enabled, and I feel so imperfectly, to bring before you, I have 'to answer' the question with which we set out.

Modern scientific thought is due to an inquiry into Nature and her works, irrespective of all preconceived theories, and the breaking away from the authority which other departments of human thought and faith have in former ages imposed upon some of the earlier inquirers into science.

Faith in religion has been defined as 'the substance of things hoped for, the evidence of things not seen,' which is altogether apart from the other and wider faith with which the scientific inquirer contemplates that vast, that stupendous, that beautiful universe which has been revealed to him by the teaching of his predecessors, and which inspires him with those hopes to which I have just alluded.

On the teaching of the ancients Bacon remarks: 'The opinion which men entertain of antiquity is a very idle thing, and almost incongruous to the world; for the old age and length of days of the world should in reality be accounted antiquity, and ought to be attributed to our own times, not to the youth of the world which is enjoyed among the ancients, for that age, though with respect to us it be ancient and greater, yet with regard to the world it was new and less.'

This idea is perhaps more and more beautifully expressed by Tennyson in the words 'I, the heir of all the ages in the foremost files of time.'

And in another respect, taking Bacon's teaching which he so often reiterates, as being a search after fruits, we must not imagine that the fruits of which he speaks are necessarily to be gathered in by the worker himself. For the pursuit of true science is often hindered by the too greedy effort to grasp the sordid rewards of the present, and, alas! Bacon himself will ever stand as a most painful example of the depth of degradation to which even the highest minds may fall.

We must learn from Nature what she is continually teaching, that her efforts are directed, not solely for the benefit of the individual, but for the welfare and the advancement of the race.

The fruits and the rewards which grow from a study of Nature, and a truly scientific effort to expound her laws, are of a higher and a wider scope.

And in contemplating the work of the great men of the past with whose names we have been so freely dealing, looking at the present attitude of the scientific mind, and our share in the application and directing of those great sources of power in Nature, we may say:

'No more a wind-borne leaf upon the waves
Of time and chance, but one to whom is given,
To help the mighty purpose of the world,
To straighten crooked paths, to smooth the hills
Of sin and sorrow, that on some bright day
The great wheels of the world may run their course
Without one jar or check.'

The following Papers were read:—

1. *Water Supply, with a Description of the Bradford Waterworks.* *By* J. WATSON, *M.Inst.C.E.*[1]

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2. *The Disposal of House Refuse in Bradford.* *By* J. McTAGGART, *A.M.I.M.E.*

The author gave particulars as to the quantity of refuse collected, the quantity destroyed by the destructors, and of the quantity tipped or sold.

[1] Published *in extenso*, Bradford, 1900.

Particulars were given as to the number and capacity of refuse destructors in Bradford, and a complete description of the Hammerton Street destructor, and the results of a seven days' test on this destructor were supplied.

The utilisation of the residuum or clinker from the destructors, its use in mortar making, and the clinker-crushing and screening machinery were described.

A short account was also given of the utilisation of the steam produced by the destructors, and a description of a new destructor in course of erection at Southfield Lane.

FRIDAY, SEPTEMBER 7.

The following Papers were read:—

1. *Resistance of Road Vehicles to Traction.* *By* Professor Hele Shaw, *LL.D., F.R.S.*

About the time of the general introduction of railways considerable attention was directed to the nature of the resistances encountered by vehicles upon the common road, and the researches of Correze, Edgeworth, Coriolis, Morin, Tredgold, Dupuit, and others must be regarded as having thrown considerable light upon the subject. From time to time recently others have done work in this direction, but there is no doubt that the attention directed to traction on railways has thrown the scientific investigation of the subject of common roads almost entirely into the background. During the last few years, however, it has been realised that there was a great field for the development of traction, and particularly by mechanical means upon the common roads, and the improvement which has been quietly taking place in the construction and maintenance of roads is a feature of national importance. Not only is the condition of the pavements in the cities and towns much improved, but in out-of-the-way districts, such as in the hilly parts of Cumberland and Westmorland, the use of steam rollers by the County Councils has effected vast improvement in the state of the roads. Various causes have contributed to this result, but it is worthy of notice that whereas when the coaching days became comparatively a thing of the past the roads fell into neglect, so now the increasing number of cyclists and tourists who visit country places are an appreciable factor worthy of consideration and encouragement by the local authorities. The recent remarkable and growing development of motor vehicles with a legal limit of speed as high as twelve miles an hour, and the generally increased speeds of tram-cars in cities owing to the introduction of electricity and steam, give some reason for thinking the general rate of speed on common roads may reach, or even exceed, the present legal limit applying to motor vehicles. As showing the mechanical possibilities in this direction, it may be pointed out that quite recently in France between forty and fifty miles an hour has been safely maintained for more than 300 miles upon the common road. Such a speed—or anything approaching to it—would not be allowed in this country, but the fact remains that it is possible with safety. With heavy traffic the legal limit for a self-propelled waggon of about two tons tare, capable of carrying several tons, is no less than eight miles an hour, and the heaviest traffic with a tare limit of vehicle of three tons, probably carrying a load of eight or ten more, is as high as five miles an hour.

These facts, and the introduction generally of mechanical propulsion, point to the necessity of having a fairly complete knowledge of the resistance of common roads of various kinds upon different classes of vehicles moving at different speeds. In the brief historical account given by the author of what has hitherto been done in this direction it will be seen that the experimental means of traction has without exception—as far as the author is aware—been limited to traction by horses; and as at any rate the earlier experiments were made with the view of horse traction, only two speeds were taken into account, viz., walking and trotting. Considering the variation in speed of horses under these two conditions, these terms

cannot be said to express anything very definite, and certainly afford no guidance whatever as to the resistance of self-propelled vehicles at various speeds. Again in recent years large sections of cities have been paved with asphalte and wood, while the laying of setts or stone pavements has undergone considerable modification, which is readily seen by an examination of a modern street and one of ten or fifteen years ago. Another modern development is the introduction of solid indiarubber and pneumatic tyres, which were at first regarded merely as a luxury, but have now proved to be an important factor in the life of the vehicle, as well as of its resistance, this being so much the case that efforts have from time to time been made to introduce the use of indiarubber tyres upon traction engines.

Beyond the foregoing points, which have not been brought under investigation in connection with the resistance of vehicles, no attempt appears to have been made to ascertain the extent to which the various factors of resistance relatively affect the whole result. Now it is evident that as the higher speeds are used, and the weights are increased, vibration and shock become more and more important; thus the resistance due to the rim of the wheel, and the ways in which it can be met by mechanical contrivances, must be regarded as quite a different problem from that of the springs attached to the body of vehicles, and some distinction must be made between the resistances as affected by each of the foregoing.

Enough has been said to show that there is not only matter for an inquiry which would be welcomed by makers of road vehicles, especially of self-propelled road vehicles, but that such an investigation, if it is to be of any real value, must be thorough, and requires not only some expenditure of money, but cannot well be undertaken by any single individual. The great interest which was excited by the paper read by Mr. Thorneycroft at the last meeting at Dover of the British Association, and the previous communications which have passed between the author and the President of this Section, who is himself a high authority upon the question of roads, have led to this matter being brought forward with the idea of forming a committee of the British Association for the investigation of road resistance.

In order to facilitate the work of the Committee, a summary of previous investigations in this subject has been prepared, which can be laid before the members, if it is formed. Some preliminary experiments have also been made with a view to obtaining some idea of the nature of the apparatus required, and the amount of expense likely to be entailed.

Preliminary Experiments.

Allusion has been made to the fact that all the previous experiments have been performed by means of the traction of horses: it seemed with the introduction of powerful motor cars it might be able to pull steadily any vehicle at any required speed. This idea really forms the chief feature of the proposed experiments, as it is evident that if one motor car is not sufficient two or more could be harnessed to the vehicle which is to be drawn. In order to ascertain how far this idea was practicable, Mr. J. A. Holder, of Birmingham, who owns a 12 h.p. Daimler car, was kind enough to visit Liverpool, and on Tuesday, Wednesday, and Thursday, July 17, 18, and 19, a series of experiments, in which the author was assisted by two former students, Mr. Humfrey, B.Sc., and Mr. Cormack, B.Sc., were made, Mr. Holder's autocar towing the author's New Orleans Voiturette. These experiments took place over roads of asphalte, wood, setts, and macadam in the neighbourhood of Liverpool, both level and up the steepest gradients which could be found, viz., Everton Brow, the details of which were given in a wall diagram. It will not serve any useful purpose at present to give the detailed results of these experiments, as they were obviously incomplete, and pointed to the absolute necessity of more elaborate apparatus of a self-recording nature; but it may be of interest to explain the apparatus actually employed, so as to indicate what will be required to insure satisfactory results.

The apparatus consists of two parts, which were illustrated by wall diagrams (1) a dynamometer, and (2) a speed indicator:

Dynamometer.—This consisted of an ordinary spring balance, the back of

which was riveted to a cylinder of a small steam engine which acted as a dash-pot. The ports of the steam cylinder were closed up, and a small hole drilled into the piston was found quite sufficient when the cylinder was filled with oil to check the free oscillations of the spring.

Speed Indicator.—The speed indicator was a Schaffer and Budenburg tachometer to which a temporary wooden wheel was attached, and a special dial was made, so that instead of indicating revolutions per minute the miles per hour at which the vehicle was travelling were at once made visible. The mode of conducting the experiments is shown by a photograph. A rope about 20 feet long was attached to the Voiturette and connected with the dynamometer, the dial of which an observer was able to read. At the same time a second observer called out the actual speed of the vehicle at that instant and the nature of the road which was being passed over, which were recorded by the first observer in his notebook, together with the pull on the dynamometer.

The net result of the experiments showed that, even on apparently the smoothest road, the variation in the pull was so considerable that nothing but appliances which would record autographically both the pull and velocity at the same instant and indicate also the distance travelled, so as to identify the exact piece of road corresponding to the record, would be of any value. Moreover, it was evident that some autographic record of the nature of the road, as well as some instrument for recording the vibration of the vehicle which was being towed, was necessary in order to form some estimate of the effect of vibration upon the resistance. With such appliances the pull on waggons, lorries, ordinary vehicles with iron rims, pneumatic and indiarubber tyres, could be investigated for any speed, and it is not too much to hope that some definite idea of the laws concerning traction might be found, with the effect of springs, tyres, and the surface of the road taken into account.

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2. *The Viagraph.* *By* J. Brown.

The viagraph is an instrument for indicating the degree of unevenness of road surfaces, and consists in principle of a straight edge to be drawn along the road surface and provided with a profiling wheel running on the surface, the vertical motions of which are transmitted to a pencil marking on a paper band, drawn under its point by a drum revolved by gear connected to the profiling wheel. The result is a profile of the road surface full size vertically, and $\frac{1}{8}$ inch to 1 foot horizontally. Means are provided for indicating the sum of the vertical motions of the profiling wheel, which sum represents numerically the relative unevenness of the road, and is called the index of unevenness when taken for a unit length of 88 yards of road. This length is automatically measured by the instrument, and an alarm bell rung when it has been traversed. Speculations as to the causes of unevenness, the proper make of wheels and springs for a given unevenness, and calculations of the horse-power absorbed in traction due to unevenness may be founded on the indications of the instrument.

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3. *A Self-registering Rain-gauge.* *By* W. J. E. Binnie.

This rain-gauge is constructed so as to register the rate of rainfall at any moment by means of the drops falling into the interior of the gauge from the orifice of the collecting funnel.

The weight of each drop depends upon—

1. The surface tension between air and water.
2. The dimensions of the orifice.
3. The interval which separates the fall of the drops.

1. The surface tension varies with the temperature, amounting to about $\frac{1}{1200}$ per degree Fahr., giving a probable maximum error of $2\frac{1}{2}$ per cent.

3. The influence on the size of the drops of the interval between the fall of

each is very marked when that interval is less than five seconds; but the relative dimensions of the funnel and the orifice are so chosen that sufficient interval for the formation of the drop is allowed even with very heavy rainfalls.

The funnel is so arranged as to discharge into a tube containing the drop former. From the orifice of the drop former each drop falls and impinges on a pan carried at one end of a counter-balanced lever. The momentum of the drop striking the pan causes that end of the lever to be depressed, so that a small pointer rigidly attached to the lever dips into a cup of mercury, closing the electric circuit to the receiver. The counter-balance then brings the lever back to its original position in which the circuit is broken.

The rain, after falling from the pan, passes into a collecting vessel by means of which the readings can be checked, and which would also obviate the loss of a record in case of anything going wrong with the instrument.

In this way each drop as it falls sends a current through to the receiver, which may be placed anywhere.

The receiver consists of a drum driven by clockwork, to which is attached a diagram in the usual manner. This diagram is divided vertically into time intervals, and horizontally so as to read in inches of 'rainfall,' the scale being dependent on the relative dimensions of the collecting funnel and drop former. Each current transmitted to the receiver works an electro-magnetic escapement in such a manner as to move a pen on the diagram through a certain space vertically.

By this means the total rainfall and the variations of rate of rainfall are registered on the drum.

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4. *The Coal Fields and Iron Ore Deposits of the Provinces of Shansi and Honan and Proposed Railway Construction in China. By* J. G. H. GLASS, *C.I.E.*

The general object of this paper was to furnish information respecting the opening up by British capital of the two large provinces of Shansi and Honan, and developing the vast and practically unparalleled mineral wealth they contain, by the construction of a system of railways, starting from the coal-fields of Shansi and connecting with the Yangtzi River opposite Nanking on the south-east and the Wei River on the east, at a place called Taokou. At the proposed terminus opposite Nanking, the Yangtzi River is open to sea-going vessels, and at Taokou, the other terminus, the Wei River is now navigable for barges having a capacity of from twenty-five to thirty tons as a maximum, and by the expenditure of a moderate sum in deepening and widening certain parts, navigation would be greatly improved. The large and commercial town of Tientsin is reached from Taokou by means of the Wei River and the Grand Canal, on both of which there is free navigation throughout the year, excepting for a short period in the winter of varying duration, when it is closed by ice. The coal-fields will thus be brought into communication with the seaboard at Nanking in the south and Tientsin in the north. The railways will besides connect with numerous waterways intersecting the country traversed, most of which are navigable, affording a cheap and convenient means of conveying coal, &c., to the dense population inhabiting the Great Plain of China.

The paper gave a description of the bituminous and anthracite coal-fields of Shansi and Honan, visited either by the author or by members of his expedition last year, and the approximate area of the coal-measures and contents available. Analyses of specimens of the coal, brought to England for that purpose, were furnished, and information given on the methods of mining adopted by the Chinese, the output at the mines visited, and the cost at pit-head. Photographs of a typical coal-mine, showing the workmen, coal-stacks, and the vehicles used for transporting the coal, were shown to illustrate the paper, and maps of the country, showing the proposed railway routes. The paper described the great deposits of iron ores associated with the coal-fields of Shansi, and their general

distribution and occurrence; analyses of them were given, and the methods followed by the Chinese in their reduction described. Sketches were given of the furnace employed, the manner of loading it was explained, and details were given of the results obtained, and an estimate was furnished of the yearly output gathered from reliable sources, and the cost of production. The description was illustrated by photographs. The existing means of communication by land and water was referred to, and information collected by the writer furnished in respect to the vehicles and pack animals used for carriage on roads, and the cost of transporting the products of the mines under present conditions. A description, accompanied by photographs, was given of one of the great high roads of China, the methods of its construction and alignment, and the difficulties which it presents to vehicular traffic briefly alluded to. Some information was also furnished regarding wages of skilled and unskilled labour, the general condition of the people, their food and habits, the effects of the last great famine on them, their demeanour towards foreigners as experienced by the writer and his staff, and as gathered from statements received personally from missionaries who have long resided in the country, and the desire evinced, not only by the workmen themselves, but also by officials, to see the natural industries developed whereby regular employment and good wages would be obtained. The implements used by the Chinese in mining and other industries, and their methods of agriculture were alluded to. A general description of the country to be traversed by the proposed railways, its physical aspects, population, and trade, was given, and also an account of the rivers and waterways encountered, with special reference to the Yellow River, and the measures to be adopted for bridging it. The gauge on which the railways are to be built, and the nature of the permanent way and rolling stock were referred to, and also other matters of interest in connection with construction. The paper also contained some remarks on existing and projected railways in China. It concluded with some general remarks on the cost of the lines of railway referred to, and haulage rates.

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5. *The Use of Expanded Metal in Concrete.*
By ARTHUR T. WALMISLEY, *M.Inst.C.E.*

The author's paper began by stating that the subject of the judicious introduction of iron and steel sections into concrete was a leading topic of discussion at the present time among engineers, and he referred to the paper read at the Liverpool meeting of the British Association descriptive of the manufacture of expanded metal by Mr. J. F. Golding, the inventor of the machinery for its production, and then dealt with its development, with special application to its introduction into concrete for supplying that tensile element which concrete without metal lacks. The present machinery is limited to sheets eight feet in length, but larger machines are in contemplation for the Expanded Metal Company's works at West Hartlepool, to enable sheets of metal long and strong enough for spans of 16-foot slabs to be supplied. The author assumed that the safe-working unit stress for concrete in compression is ten times the safe-working unit stress for concrete in tension, and pointed out that, under these circumstances, with a homogeneous section of pure concrete having parallel sides the neutral axis must be above the level of the centre of gravity of a slab laid horizontally or vertically; and that, assuming—as in the case of a slab supported at the edges—that it is laid flat, the neutral axis of a section divided the depth into the proportions of ·24 and ·76 respectively in order to create a result equal to a couple in which the compressive and tensile elements unaided by metal would be in equilibrium. The author then gave calculations showing the effect of introducing metal into the tensile portion of the section, whereby the neutral axis under the above conditions of equilibrium is lowered, the compressive portion is increased, and the neutral axis made to approach nearer the centre of gravity of the section. Examples were given of a section containing wires or rods, plates, and inverted tee sections, together with a comparison of a section containing expanded metal; and the author pointed out that the latter provides a uniform distribution of tensile strength in all directions,

ample in amount without extravagance, and easily laid without the responsibility of supervision in placing the material transversely at the specified distances apart, as would be necessary in the case of separate pieces. The insertion of wires or individual sections gives strength in the direction of their length, leaving the intermediate concrete comparatively weak. Expanded metal contributes strength laterally both in the direction of width and length, as well as giving an effective keyage in its depth. The coefficients of expansion of the two constituents, iron or steel and concrete, are considered for all practical purposes to be identical. Results of experiments made on various-size slabs were next given, the longest span without intermediate joists being on a slab 12 ft. 6 in. by 11 ft. clear span, which was loaded to $5\frac{1}{4}$ cwt. to the foot super, and bore this load for $1\frac{1}{2}$ hour before it collapsed, the fractures occurring at each of the four corners. The gradual increase of the load and progress of deflection of the slab were related in detail.

The adhesion of iron and concrete was found by Professor Bauschinger, of Munich, to be about 569 to 668 pounds per square inch, but a case was quoted, experimenting upon 2 in. diameter anchor bolts set $11\frac{1}{2}$ in. in a masonry block, with lead, sulphur, and cement, from which it was inferred that in suitable setting the cement joint on a smooth rod might be made to fracture the rod before the adhesion of the connection failed. The author described the introduction of the aid of channel arches by the Expanded Metal Company. The spans were enabled to be increased thereby, the only objection being, in the author's opinion, the exposure of the under surface of the channel metal rib; but the surface so exposed is comparatively small compared with the various systems of trough flooring that have been patented. The result of experiments was stated in the paper, the channel metal flat arches being firmly held between longitudinal joists spaced at specified intervals. The author considered that, in order to keep the portion of a slab containing metal in tension below the neutral axis, the slab should not be fixed at its bearings; but he pointed out that probably there is a tendency to form a flat arch within a concrete beam, which converts a large part of the vertical pressure into lateral thrust, which in the case of an expanded metal section becomes a tied arch, and that, in his opinion, a concrete beam should be viewed as a bar with a hollow curved soffit. Further developments of the system were reviewed, and diagrams illustrative of the arguments propounded were exhibited, with a view to elicit suggestions as to any desired improvement in the size of the meshes employed or to further experiments needed.

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6. *Power Generation.—Comparative Cost by the Steam Engine, Water Turbine, and Gas Engine.* *By* JOHN B. C. KERSHAW, *F.I.C.*

There is no question of greater importance at the present moment to those engaged in the management of our manufacturing industries than that of power generation. The supremacy which the steam engine has so long enjoyed is now assailed from two sides. The water turbine and the gas engine have become dangerous rivals.

During the past ten years a most remarkable development of hydraulic power has been taking place on the continent of Europe in France and Germany, and in America at Niagara.

The aggregate amount of power at the present date generated from falling water forms no inconsiderable portion of the total power utilised in manufacturing industries; and two years ago it was estimated by the author to be between 236,000 and 350,000 horse-power.

On the other hand gas engineers have been busily engaged in working out the problems presented by large gas engines and by the utilisation of the waste gases of blast furnaces.

Gas engines up to 650 horse-power have been built, and have worked smoothly and economically; while at Seraing in Belgium and at other places the blast furnace gases have been utilised for driving the engines which supply the blast.

The question, therefore, which the engineer now has to settle when deciding upon the site and locality for a new factory, or when deciding upon the system of

power generation to adopt for extensions of the old, is no longer so simple as when only one method of power generation in large units was open to him.

It is no doubt true that the choice between the three possible sources of power is one which in many cases will be settled purely by local considerations; and the proximity of a large waterfall or of an extensive coalfield to the factory, will be held to point to the turbine or to the steam engine as the most economical power generator. In a great number of cases, however, especially when the decision of the engineer covers the choice of a site for the factory, the problem is capable of no such easy solution; and the most economical source of power can only be determined after an exhaustive study of comparative costs data.

The aim of the writer in the present paper has been to collect and arrange in comparable form some of the more important figures bearing on the cost of power generation. Full references are given to all the original articles from which these figures are drawn.[1]

Taking the best figures for each of the three sources of power dealt with above, and bringing them all to a common basis of comparison, namely, the cost of the E.H.P. year of 8,760 hours, the author obtained the figures given below.

TABLE VII.—*Comparative Costs of Electrical Power.*

Source of Power	Lowest Cost per E.H.P. year of 8,760 hours			
	Estimated	Locality	Actual	Locality
	£ s. d.		£ s. d.	
Water	1 5 5	Canada	1 19 0	Switzerland
Steam	4 18 8	North England	4 9 7	United States
Gas (Producer)	5 0 0	England	—	—
Gas (Blast Furnace)	4 1 7	Germany	—	—

The figures in the table support the opinion, now generally held, that water when developed without excessive capital expenditure is the cheapest source of mechanical or electrical energy. When, however, the hydraulic engineering expenditure has been heavy, or when the power after generation has required to be transmitted over long distances, the margin between the relative costs of water and steam power is greatly narrowed, and in some cases disappears.

Electrical energy generated by falling water is costing more at Rheinfelden, at Zurich, and at Buffalo than it would cost in South Lancashire if generated by steam power in large units; and the margin between the actual charge for power at Niagara and the estimated cost of steam power in large generating stations in South Lancashire is only 12s. 1d. per E.H.P. year.

In this connection it is interesting to note that the charge for electric power in Buffalo is 13*s.* 6*d.* per E.H.P. year higher than at Niagara; and the excessive charge to small consumers in the same city (25*l.* 11*s.* per E.H.P. year) would seem to indicate that the cost of transmission between Niagara and Buffalo represents at least 20*s.* per E.H.P. year on the power sent into that city.

Turning now to a consideration of the relative position of gas power, the question of the practicability of large engines may be taken as settled. If they do not cost excessive sums for maintenance and repairs, large gas engines, in conjunction with coke ovens and blast furnaces, may entirely alter the present position of affairs; and the new industries which at present are being established in the neighbourhood of water-power stations may find themselves in severe competition with similar manufactures carried on in the coal and iron districts of the older manufacturing countries.

It has been calculated that 2,000,000 H.P. is annually wasted in the gases issuing from the blast furnaces of the United Kingdom. If these waste gases

[1] Tables I. to VI. contain details of sixty-five actual or estimated costs of steam, water, or gas power per H.P. year of 8,760 hours.

could be industrially utilised in the manner suggested, we should to a large extent be compensated for our lack of natural water power.

But blast furnaces demand coke, and coal beds are exhaustible, so that even if this source of mechanical and electrical energy be tapped it can only postpone, but not avert, the final triumph of the waterfall and of the turbine.

SATURDAY, SEPTEMBER 8.

The Section did not meet.

MONDAY, SEPTEMBER 10.

The following Papers were read:—

1. *The Automobile for Electric Street Traction. By* J. G. W. ALDRIDGE.

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2. *The Manchester and Liverpool Express Railway. By* Sir W. H. PREECE, *F.R.S.*

A monorail line has been projected by Mr. Behr between Manchester and Liverpool to accommodate express passenger traffic alone between those two cities. It is to be worked by electric traction and to attain very high speeds. The train is to consist of only one coach, weighing forty-five tons and seating sixty-four passengers. Starting at every ten minutes, and travelling at the mean rate of 110 miles an hour, it will do the distance of $34\frac{1}{2}$ miles in twenty minutes. The fares will be slightly lower than those charged at present. There will be no intermediate stations, no points or crossings. There will thus be no necessity for signals to protect the line during other operations. Signals would be needed only to secure a perfect block system of working the line. The monorail railway was projected by Lartigue in 1882.

We have only one example of this system of railway in the United Kingdom, viz., between Listowel and Ballybunion, in County Kerry, Ireland. This line was designed and engineered by Mr. Behr. The Act was obtained in 1887, and the line was opened for traffic in February, 1888, and it has been running ever since. The line is $9\frac{1}{4}$ miles long. It has one intermediate station, Liselton. There are forty-two level and farm crossings. It is worked by steam. The train consists of a locomotive and four coaches. It cost 33,000*l.* to build, or 3,060*l.* per mile. When I inspected the line in the early part of this year there had never been a Board of Trade inquiry into any accident. The maintenance of the structure had been effective. No rail had ever been turned. The mechanical structure had exhibited no defects, but several breakdowns had occurred in the locomotive and rolling stock. There are three locomotives, eleven passenger coaches, and two brake vans. They had, however, continued to work the line uninterruptedly for twelve years, and there had been no renewals or new stock. Its main principle is the suspension of the coaches on a single elevated rail so that their centres of gravity are below the rail. Each coach sits the rail like a saddle. The rail is fixed on trestles; which are tied and braced together, the tie bars being light rails against which guide wheels roll.

The Manchester and Liverpool Express is intended to be more massively and rigidly built. Derailment on such a structure is impossible, and curves of comparatively small radius can be passed with safety at high speeds. Vibrations and noise will be reduced, and travelling will be conducted with greater comfort than at present.

It is proposed to fix the generating station midway at Warrington, and to transmit the electric energy at high pressure (10,000 volts) to each terminal

station. There would be sub-stations along the line, at distances apart of four miles, where the 10,000 volts would be brought down to 1,000, at which pressure it would be picked up by the motors on the coach.

The speed which a train can acquire on a railway depends on the power that can be continuously applied at the thread of the driving wheel. Electricity enables the engineer to apply instantaneously to light loads a power which steam cannot supply. Hence speeds are possible with electricity which are unattainable with steam. A coach weighing forty-five tons can easily and quickly attain 110 miles an hour. 1,600 horse-power will accelerate the coach so as to attain this speed in 110 seconds, and 500 horse-power will maintain this speed on the level. Electricity has two advantages over steam. It enables us to obtain an acceleration of $1\frac{1}{2}$ feet per second, which is virtually the limit that can be obtained without causing discomfort to the passengers; and, secondly, it applies a continuous and constant torque instead of the variable one due to the reciprocating action of the ordinary steam locomotive. Hence it not only enables us to maintain high speeds on long through lines like the proposed Manchester and Liverpool Express, but it enables us to attain high speeds with greater rapidity on short lines having frequent stoppages, like the Metropolitan railways of London, and thus increase the capacity of the line for traffic.

The chief causes of accident on ordinary railways, viz., collision, derailment, points, and the human error of the signalman, will be removed from lines. Hence travelling will be much safer.

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3. *Manchester and Liverpool Electrical Express Railway: Brakes and Signals. By* F. B. Behr.

The questions of brakes and signals are so intimately connected that the one cannot be treated separately from the other.

The most perfect condition under which a railway could be worked would be that in which both brakes and signals could be dispensed with; therefore it follows that the fewer the occasions for using either, the better.

Now as to brakes, there is a limitation of their application, which depends not so much on the mechanical appliances themselves as on the endurance of the passengers. It was stated by an eminent railway official to the Select Committee of the House of Commons that with the Westinghouse brake a train travelling at 60 miles an hour could be stopped at an emergency, within 360 yards, without inflicting too great a shock on the passengers. In the same way the proposed train travelling at 110 miles an hour could be stopped within 500 yards, and probably in a shorter distance, as in this case electrical means would be at hand, such as the reversal of the motors, so as to turn them into dynamos. More rapid stoppages could only be made with great discomfort to the passengers. Now in the ordinary way of working our railways at present there are many occasions in which it might be important to stop the train as rapidly as possible; for instance, if a train should be seen in front, or some shunting operations were not completed, or in some other cases too many to enumerate. But no brake, however powerful, would be of the slightest use to-day for avoiding a sudden obstacle, such as a stone placed on the rail, or a broken rail, for it is impossible for the driver to be aware of such obstacles until he is practically upon them. In these cases, therefore, the power of stopping at 300, or 200, or even 100 yards is quite useless.

The author then stated that on the proposed high-speed electrical railways, though it is quite possible to stop the train within less than 500 yards, it never can be necessary to bring it to a standstill at even a much longer distance.

On the proposed railway there will be no level crossings, no switches, no shunting operations, and in fact nothing that will require the train to be brought to a standstill unless a preceding train should break down. Besides this one case, the brakes can only be used for stopping as you approach the stations. A broken rail produces no danger whatever, for the train would run over it without any risk or difficulty. This can easily be shown by carefully

considering the relative position of the wheels of the carriages to the rails over which they travel.

It remained, therefore, only to explain the manner in which it is arranged that the driver of each train shall be informed of the possible stoppage of the train in front of him.

Under normal conditions no second train will leave the station at Manchester or Liverpool until the first has reached Warrington, a distance of over 17 miles.

The line will be subdivided for the purpose of signalling into eight sections of 4·3 miles each. As a train leaves Manchester or Liverpool a danger signal is put up automatically at that station, and a second similar danger signal is put up in the same way at 4·3 miles off, the first remaining at danger. The train travels on until it reaches 8·6 miles, when it puts up a third danger signal, and simultaneously the signal is lowered at Manchester or Liverpool, so that the second train can now leave.

Assuming that the first train has met with an accident after passing the point distant 8·6 miles, the second train would travel at full speed until it passes point 4·3 miles. The danger signal at that point not having been removed by the first train, as it never reached point 13 miles, the driver of the second train would be informed that the first train had met with an accident between 8·6 miles and 13 miles, and therefore that he has to slow down, but that for such lowering of his speed he has a clear run of over four miles. Therefore, there could be no difficulty in stopping without using the brake at all by simply cutting off the current.

Whenever a train passes over a point where the danger signal is put up this is reproduced, either electrically or mechanically, by a very simple and inexpensive contrivance in the cabin of the driver, so that he would be perfectly able to see it without difficulty even if there was a thick fog.

Under these conditions of travelling it seems, therefore, superfluous to have any emergency brakes; and though it will be possible to stop the trains within 500 yards, no case can be imagined in which it would be useful or necessary to resort to such a stoppage.

A six minutes' service of trains could be established without any alteration in the proposed arrangement, and if a three minutes' service was required the blocks would have to be reduced to two-mile sections, giving a clear run of two miles in case of a breakdown.

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4. *The Construction of Large Dynamos, as exemplified at the Paris Exhibition. By* Professor S. P. THOMPSON, *F.R.S.*

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5. *Recent Tramway Construction. By* W. DAWSON.

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6. *Measurement of the Tractive Force, Resistance, and Acceleration of Trains. By* A. MALLOCK.

The author described in the paper some experiments recently made on electric and other railways, the object of the experiments being to determine the acceleration, tractive force, and running resistance to which the trains are subject.

The appliance used was a short pendulum whose free vibrations are adequately damped. If this is suspended on the moving body it will hang in the direction which is the resultant of gravity and the acceleration which the body at the time experiences; hence the angle which such a pendulum makes with the vertical gives the measure of the accelerations at each instant.

In the experiments the pendulum was arranged so as to record its position on uniformly moving paper, on which at the same time seconds were marked by an electric clock, and a contact marker, worked from one of the wheels of the carriage, caused a second pen to record each revolution performed by the wheel. The

diagram thus obtained gives a direct measure of the speed and acceleration of the carriage.

The author showed that pendulum observations, combined with a record of speed and power supplied, offer a simple and effective means of determining the resistance to, and efficiency of, electric or other kinds of motor vehicles.

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7. *On a Combination integrating Wattmeter and Maximum Demand Indicator.* *By* T. Barker.

The paper fully sets forth the advantages of the maximum demand system of charging for the supply of electricity, and describes a new meter—the invention of Messrs. Barker and Ewing—to be used for this purpose. The paper was illustrated by diagrams, and examples of the meter were exhibited.

In charging for the supply of electricity it has become usual to make a distinction in the prices charged to those consumers who use a few lights for many hours per day and those who use many lights for an hour or less; for, although at the end of the year the number of units consumed may be the same in both cases, the cost to the company or corporation in machinery, mains, and every other charge will be in the ratio of the number of lamps lighted at one time. The consumer who uses a few lamps for many hours should be charged at a less rate per unit in view of the smaller capital expenditure which his supply involves.

The late Dr. Hopkinson advocated a system which takes account of this consideration in arriving at the fair price to be charged for current. In the system in question, now known as the 'Maximum Demand System,' the total quantity of electricity consumed in six months is measured in the usual way, and the greatest rate at which the consumer has been taking current is also recorded. If the consumer in the six months' period takes a smaller total than would correspond to one hour a day at the greatest rate of demand, he is charged the full price per unit, but if the total consumption exceeds this he is charged a reduced rate for each unit in excess.

The system has been used with marked success in some seventy-two towns. It has improved the load factor, and has enabled a large number of additional units to be sold without increase of station plant or mains. Until the introduction of Barker and Ewing's Demand Indicator it was necessary to use two meters —one to record the total number of units taken by the consumer and the other to show his maximum rate of demand.

The Barker and Ewing Indicator forms an integral part of the ordinary meter, and absorbs no energy; it further records watts and not amperes. With an alternating supply it shows actual watts and not apparent watts, an important difference in the case of motors and arc-lamps. It is not affected by any ordinary short circuit, its time lag being sufficient to prevent it coming into action. The Indicator may be used to show the actual rate of demand at any instant in place of recording the maximum rate of demand. In this form it is specially useful in switchboard instruments, showing the attendant the rate at which electric energy is passing through a feeder or is supplied from a dynamo at any instant. The meter also serves at the same time to integrate the total amount which has passed through that particular feeder or machine.

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8. *The Design and Location of Electric Generating Stations.* *By* Alfred H. Gibbings, *M.Inst.E.E.*

The term 'central station' is gradually being supplanted by more comprehensive designations.

All design and arrangement in regard to electric works must be with a view to securing the highest average efficiency together with reliability in operation. Electric works at present do not fulfil these conditions, but that may excusably be accounted for because it was impossible to foresee modern developments. Electricity, at first used for lighting only, has now come to be used in the form

of electric motive power and electric traction. The attempt to supply all these from one generating station has led to the use of unsuitable plant, to confusion in the station itself, but at the same time to a reduction in prices charged. It has also resulted in a large variation in capital cost per kilowatt of plant. Small and isolated undertakings try to attain equally successful results by other experiments, but fail. Economical production is only possible where both the generating costs and the standing charges are reduced together as the load increases and the system extends. To effect this generating works must in future be constructed and located with a view to include the supply of energy for motive power, tramways, and electro-chemical purposes. Details of such construction and location should embody the following points:—

(1) The machinery must be designed to generate at high voltage, differing according to the extent of the area and the nature of the system, but it must be suitable for transformation at sub-stations to meet all possible requirements.

(2) The type of all boilers, engines, electric generators, switchboards, &c., must be simple and mechanically reliable, even at the sacrifice of some slight maximum economy.

(3) All complicated gear and fanciful combinations, such as might lead to possible breakdown, must be avoided throughout the entire arrangement.

(4) As far as possible the different units of the respective types of plant should be uniform in design and arrangement and made to one standard size, thus economising in labour, avoiding large 'stand-by' plant and spare gear.

(5) The buildings should be devoid of all unnecessary embellishments, nor should an attempt be made to confine too many departments under one roof.

(6) The location should be such as to ensure a cheap and ready supply and delivery of fuel, and where condensing can be accomplished efficiently and inexpensively.

TUESDAY, SEPTEMBER 11.

The following Report and Papers were read:—

1. *Report on Small Screw Gauges.* See Reports, p. 436.

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2. *On Screw Threads used in Cycle Construction, and for Screws subject to Vibration. By* O. P. Clements.

The Chairman of the Screw Gauge Committee of this Association has honoured me by the request that I would contribute a short paper on screw threads which, in my experience, have proved to be the most suitable for use in cycle construction and for screws that are subject to vibration. In complying with this request I propose to confine myself chiefly to the consideration of what is of most importance in this connection, namely, the shape of the threads. The time limit allowed for this paper would be inadequate for dealing exhaustively with such matters as pitch in relation to diameters, interchangeability, and gauging.

In my opinion it would be impossible to devise a standard thread suitable for all classes of work and the various conditions of use. At present there are not only standard threads differing so much in shape as the Whitworth and the American, but also a large number of bastard threads, differing in shape from either of these, and which have been adopted in most instances as a matter of expediency and necessity. A too slavish use of a standard thread has no doubt often been the cause of much mischief and inconvenience in its adaptation to purposes for which it was unsuitable.

When Sir Joseph Whitworth framed his system of threads and pitches he had not at his command the superior quality of steel for the manufacture of screws which we have in the present day. If he had, I venture to think that his system would have been somewhat modified both in shape of thread and in pitch.

I think that the correctness of these views cannot be better demonstrated than by showing what is the general practice and experience with regard to screws used in the gun trade. In both sporting guns and military rifles the screws are subject to severe vibration as well as sudden strains, and are therefore extremely liable to work loose. To obviate this the gunmaker uses a thread with a well rounded top, and care is taken that the whole of the thread fits well, but more especially the top of the thread, where the frictional contact on the greatest circumferential portion of the screw will prevent loosening. We have thus a thread that differs from any recognised standard. It is shallow, with a large angle of the sides generally about 60°, and is admirably suited for the purpose of resisting vibration.

I will now refer to a shape of thread which merits consideration, namely, flat-topped threads, which are very suitable for many purposes. It is also a shape of thread to which most accurate gauges can be made; but while admitting their undoubted suitability for gauge making, I must remark that gauges for threads with rounded tops can also be made satisfactorily, for all practical purposes, both as regards size and form, and so as to be perfectly reversible. Such gauge making, however, certainly requires a skill and experience which can be attained in but few tool shops. The flat-topped thread can be most accurately formed with a single tool on the ordinary screw-cutting lathes, or on machines having a leading screw or former. The tool can be easily ground to correct shape, and so as to have the cutting clearance which is necessary for the durability of the tool and for the production of clean and accurate work.

There are, however, serious objections to the adoption of such a thread for screws used in cycle work, and for screws subject to vibration. It is certain that the flat-topped thread cannot give the frictional resistance to vibration which is the case with the round top; and in the economical production of such work it would be very difficult to maintain the correct shape of the thread. In this production, screwing dies are chiefly used, and these tools show the first and most rapid wear on the parts forming the sharp edges or corners of the thread. For this reason it will be found a serious matter to keep up the screwing tackle, male and female, in the proper working condition necessary to produce flat-topped threads, especially if they should have a small angle of the sides. I am regarding this matter from the commercial point of view, that is, the production of work in quantities to be profitable and accurate, so far as accuracy is commercially possible.

In my experience the most favourable shape of thread for production with screwing dies and taps is a shallow thread with a large angle of the sides. This will give the best cutting clearance in the screwing tools. All the faults and errors in screw threads, and the difficulties in manufacture, can generally be traced to the bad cutting clearance in screwing dies and taps for high threads with small angles of the sides. Thus, through the strain put on the sides of such threads, there is a liability to breakage of the threads on the screwing dies and taps, and it also causes the screw to elongate and produces a fewer number of threads to the inch than standard pitch requires. This pitch error is a most serious fault, as the strain which should be distributed over all the threads is often taken by only one or two of them.

Owing to the rapid wear of dies and taps with a bad cutting clearance, a faulty shape of thread is produced, especially at the sides of the thread. The angle of the male thread is often different from that of the female thread, and, in such case, the bearing surface at the sides of the thread is, of course, considerably reduced. This fault is especially serious in long-sided threads.

The spreading or elongation of the thread is another matter which I may here refer to. It is found necessary in tapping holes to drill or reamer the hole larger than the bottom of the thread on the male screw. In the process of tapping, the thread elongates so as to fill the cavities between the threads and the tap, and upon the completion of the operation the hole will be found to be considerably smaller than when the tap was first inserted. This elongation also occurs in the male thread, but to a less degree, and if proper allowance for it is neglected,

ripping of the threads will be caused. Much depends, also, on the material to be operated upon. In mild steel the elongation is more than in hard steel; in brass and gun metal rather more than in mild steel; and in cast iron it is considerably less than in either of the other metals mentioned. Further, in threads with a small angle of the sides it is considerably more than in those having a large angle.

The screws used in cycle construction are subject to even more continuous vibration than gun screws, but owing also to the low margin of safety in cycle work, it has been found necessary to use shallow threads, so as to give the greatest possible strength to the core, and to obtain a large angle of the sides of thread, which especially is important, as a large number of parts are hardened, and therefore the greatest possible strength of thread is necessary. While a few firms use the Whitworth thread exclusively, others use a shallow thread, as before described, in a portion of their component parts, with Whitworth threads in the remainder. With the exception of two instances, as will be seen from the attached list, the shallow thread is adopted throughout for B.S.A. cycle components. Time, however, will not permit me to give the reasons why a different thread is used in the two exceptions, but they illustrate the necessity which sometimes arises for the adoption of a different thread to suit altered conditions.

The 'B.S.A.' thread is now extensively adopted as a standard in the cycle trade, and although the B.S.A. Company make all their own screws, the screw manufacturers to the trade have found it necessary to make the 'B.S.A.' standard a staple article of their trade, and tool makers have also now a marketable article in taps, dies, and chasers for the 'B.S.A.' thread.

The illustration which was exhibited gave the section of the 'B.S.A.' thread, and for comparison also sections of the British Association, the Whitworth, and the Seller threads. A list of the diameters, pitches, &c., of the screws used in the 'B.S.A.' cycle components was also given. It is to be noted that the angle of the 'B.S A.' thread is 60°, with tops and bottoms rounded to a radius of one-sixth of the pitch, and this is practically the shape of the thread used for the screws of the Lee-Enfield Magazine Rifle, which is manufactured for Her Majesty's Government by the B.S.A. Company.

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3. *The Photographic Method of preparing Textile Designs.* *By* Professor Roberts Beaumont, *M.I.Mech.E., Yorkshire College, Leeds.*

The preparation of designs for the loom has, throughout the history of weaving, been regarded as a purely manual process controlled by the intelligence, ingenuity, and skill of the craftsman. It is only natural, therefore, that the invention of apparatus for this specific purpose should have created much interest amongst both British and foreign textile experts. Photography, as understood and practised, appeared as incapable of aiding the artist in the actual painting of his picture as the designer in the transference and execution of the plain sketch of the pattern on to the 'scale' paper for the loom. Within the wide range of technical and scientific data in the construction and embellishment of woven fabrics there is, perhaps, no phase of the work more difficult to assail, by mechanical devices, than the application and adjustment of the manifold 'weave' units which compose all figured textiles.

Design acquired in the loom is a distinct type of ornamentation involved in varied technicalities. It is not the result of one but of a number of processes, overlapping each other, and yet uniting to construct and perfect the same woven effect. Fabric and design have to be simultaneously obtained. These can only be divorced by resorting to the arts of printing, embroidery, and painting. Obviously, in the preparation of the 'design' sketch for weaving, numerous limitations have to be encountered, which, on a first consideration, seem liable to be increased rather than diminished by a photographic process of design-development. Much ingenuity has been exercised by Szczepanik in his solution of these 'weave' problems. Szczepanik's apparatus is not for the origination of designs either in the

theoretical or technical form, for in both processes the knowledge of the expert is demanded; but its province is to lessen, and, in some instances, dispense with, the monotonous manual labour necessitated by the present system. There are large areas of point paper in elaborate designs to which the same weave effect has to be applied, and where some labour-saving device is much needed. Further, in the enlargement of the artist's sketch to scale there is much mechanical work that it ought to be possible to reduce. The photographic inventions of Szczepanik profess to accomplish these objects, and the designs submitted prove that there are possibilities of success in certain styles of pattern. A new field for experiment has been discovered, the extent of which it is not possible to forecast, but it may reasonably be anticipated that the genius and temerity of the discoverer will prove equal to its more complete exploration.

The essential purpose of Szczepanik's invention is to develop from the ordinary sketch and enlarge to a prescribed scale the technically prepared design, marked with the thousands, or may be millions, of dots grouped in different orders and so fitted together as to impart precise definition to the several portions of the woven figure or design. The process is threefold, consisting (1) of the preparation of the ruled paper; (2) the development of the design from an ordinary photographic negative; and (3) the application of the weave units to the several parts of the figure. Primarily the apparatus consists of an optical lantern with a suitable arrangement of lenses. One important factor is the 'raster' or multiplying plate, containing some 435,600 perforations, through each of which the weave type passes, and is printed on the enlarged design. In addition there are weave-plates for determining the details of the pattern, and small metal slides for producing particular sections in distinct forms of type, so that they may be as readily distinguished from each other as if sketched in various colours.

The light from the lantern passes through the negative of the design, entering a pair of lenses between which is fixed the small metal plate of the proper shape for developing the marks on the sensitised paper. The process consists in dividing and subdividing the 'scale' pattern into rectangular spaces, and of marking each with the correct weave type. When there is no negative in the lantern this type is repeated as many times as there are holes in the 'raster,' showing the feasibility of marking every square photographically on any kind of weaver's paper.

In the first place, the negative is made of the complete design, and all parts erased but the ground sections, allowing of these being printed with their supplementary weave elements. Negatives of every part of the pattern are similarly printed in succession until the entire design has been obtained. For the production of shaded work, *e.g.* portraits and pictorial subjects, selecting plates are employed. These secure an accurate graduation of tones perfectly in harmony with the photograph from which they are derived. Provision is made for the execution of patterns in compound as well as in single structure fabrics; but it follows, the more complex the build of the texture, the more intricate the process of design production. Certain textile designs may evidently be produced photographically by the Szczepanik system, so that it is now a question for demonstration whether designs so produced are comparable in legibility and equal for all practical purposes—as forcible in detail, as vital in execution—to those prepared by the much slower hand method.

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4. *Shop Buildings.* *By* E. R. CLARK, *M.Inst.C.E.*

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5. *The Internal Architecture of Steel.* *By* Professor ARNOLD.

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6. *A New Form of Calorimeter for measuring the Wetness of Steam.* *By* Professor J. GOODMAN.

7. *On the Reheating of Compressed Air.*
By WILLIAM GEORGE WALKER, *A.M.I.C.E., M.I.M.E.*

Considerable economy can be obtained by reheating compressed air before admitting it to the engine.

Reheating is accomplished by two methods:—

1. By passing the air through hot pipes heated by a furnace fire.
2. By passing the compressed air through water in a boiler at a temperature depending on the pressure in the boiler.

The author and Mr. P. Y. Alexander have investigated these methods. Generally speaking, the results show that an additional horse-power can be obtained with an expenditure of one pound of coal, which is more efficient than the most economical engine and boiler using steam.

The experiments show that in many cases it would prove advantageous to use compressed air in conjunction with steam in an ordinary engine.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION—Professor JOHN RHYS, M.A., LL.D.

THURSDAY, SEPTEMBER 6.

The President delivered the following Address:—

PERHAPS I ought to begin by apologising for my conspicuous lack of qualification to fill this chair, but I prefer, with your permission, to dismiss that as a subject far too large for me to dispose of this morning. So I would beg to call your attention back for a moment to the excellent address given to this Section last year. It was full of practical suggestions which are well worth recalling: one was as to the project of a Bureau of Ethnology for Greater Britain, and the other turned on the desirability of founding an Imperial Institution to represent our vast Colonial Empire. I mention these things in the hope that we shall not leave the Government and others concerned any peace till we have realised those modest dreams of enlightenment. People's minds are just now so full of other things that the interests of knowledge and science are in no little danger of being overlooked. So it is all the more desirable that the British Association, as our great parliament of science, should take the necessary steps to prevent that happening, and to keep steadily before the public the duties which a great and composite nation like ours owes to the world and to humanity, whether civilised or savage.

The difficulties of the position of the president of this Section arise in a great measure from the vastness of the field of research which the Science of Man covers. He is, therefore, constrained to limit his attention as a rule to some small corner of it; and, with the audacity of ignorance, I have selected that which might be labelled the early ethnology of the British Isles, but I propose to approach it only along the precarious paths of folklore and philology, because I know no other. Here, however, comes a personal difficulty: at any rate I suppose I ought to pretend that I feel it a difficulty, namely, that I have committed myself to publicity on that subject already. But as a matter of fact, I can hardly bring myself to confess to any such feeling; and this leads me to mention in passing the change of attitude which I have lived to notice in the case of students in my position. Most of us here present have known men who, when they had once printed their views on their favourite subjects of study, stuck to those views through thick and thin, or at most limited themselves to changing the place of a comma here and there, or replacing an occasional *and* by a *but*. The work had then been made perfect, and not a few great questions affecting no inconsiderable portions of the universe had been for ever set at rest. That was briefly the process of getting ready for posterity, but one of its disadvantages was that those who adopted it had to waste a good deal of time in the daily practice of the art of fencing and winning verbal victories; for, metaphorically speaking,

'With many a whack and many a bang
Rough crabtree and old iron rang.

Now all that, however amusing it may have been, has been changed, and what now happens is somewhat as follows: AB makes an experiment or propounds what he calls a working hypothesis; but no sooner has AB done so than CD, who is engaged in the same sort of research, proceeds to improve on AB. This, instead of impelling AB to rush after CD with all kinds of epithets, and insinuating that his character is deficient in all the ordinary virtues of a man and a brother, only makes him go to work again and see whether he cannot improve on CD's results; and most likely he succeeds, for one discovery leads to another. So we have the spectacle not infrequently of a man illustrating the truth of the poet's belief,

> 'That men may rise on stepping-stones
> Of their dead selves to higher things.'

It is a severe discipline in which all display of feeling is considered bad form. Of course every now and then a spirit of the ruder kind discards the rules of the game and attracts attention by having public fits of bad temper; but generally speaking the rivalry goes on quietly enough to the verge of monotony, with the net result that the stock of knowledge is increased. I may be told, however, that while this kind of exercise may be agreeable to the ass who writes, it is not conducive to the safety of the publisher's chickens. To that it might suffice to answer that the publisher is usually one who is well able to take good care of his chickens; but, seriously, what it would probably mean is, that in the matter of the more progressive branches of study, smaller editions of the books dealing with them would be required, but a more frequent issue of improved editions of them or else new books altogether, a state of things to which the publisher would probably find ways of adapting himself without loss of profit. And after all, the interests of knowledge must be reckoned uppermost. It is needless to say that I have in view only a class of books which literary men proper do not admit to be literature at all; and the book trade has one of its mainstays, beyond all doubt, in books of pure literature, which are like the angels that neither marry nor give in marriage: they go on for ever in their serene singleness of purpose to charm and chasten the reader's mind.

My predecessor last year alluded to an Oxford don said to have given it as his conviction, that anthropology rests on a foundation of romance. I have no notion who that Oxford don may have been, but I am well aware that Oxford dons have sometimes a knack of using very striking language. In this case, however, I should be inclined to share to a certain extent that Oxford don's regard for romance, holding as I do that the facts of history are not the only facts deserving of careful study by the anthropologist. There are also the facts of fiction, and to some of those I would now call your attention. Recently, in putting together a volume on Welsh folklore, I had to try to classify and analyse in my mind the stories which have been current in Wales about the fairies. Now the mass of folklore about the fairies is of various origins. Thus with them have been more or less inseparably confounded certain divinities or demons, especially various kinds of beings associated with the rivers and lakes of the country. They are creations introduced from the workshop of the imagination; then there is the dead ancestor, who also seems to have contributed his share to the sum total of our notions about the Little People. In far the greater number of cases, however, we seem to have something historical, or, at any rate, something which may be contemplated as historical. The key to the fairy idea is that there once was a real race of people to whom all kinds of attributes, possible and impossible, have been given in the course of uncounted centuries of story-telling by races endowed with a lively imagination.

When the mortal midwife has been fetched to attend on a fairy mother in a fairy palace, she is handed an ointment which she is to apply to the fairy baby's eyes, at the same time that she is gravely warned not to touch her own eyes with it. Of course any one can foresee that when she is engaged in applying the ointment to the young fairy's eyes one of her own eyes is certain to itch and have the benefit of the forbidden salve. When this happens the midwife has two very

different views of her surroundings: with the untouched eye she sees that she is in the finest and grandest place that she has ever beheld in her life, and there she can see the lady on whom she is attending reposing on a bed, while with the anointed eye she perceives how she is lying on a bundle of rushes and withered ferns in a large cave, with big stones all round her and a little fire in one corner, and she also discovers that the woman is a girl who has once been her servant. Like the midwife we have also to exercise a sort of double vision, if we are to understand the fairies and see through the stories about them. An instance will explain what I mean: Fairy women are pretty generally represented as fascinating to the last degree and gorgeously dressed: that is how they appear through the glamour in which they move and have their being. On the other hand, not only are some tribes of some fairies described as ugly, but fairy children when left as changelings are pictured invariably as repulsive urchins of a sallow complexion and mostly deformed about the feet and legs: there we have the real fairy with the glamour taken off and a certain amount of depreciatory exaggeration put on.

Now when one approaches the fairy question in this kind of way, one is forced, it strikes me, to conclude that the fairies, as a real people, consisted of a short, stumpy, swarthy race, which made its habitations underground or otherwise cunningly concealed. They were hunters, probably, and fishermen; at any rate they were not tillers of the ground or eaters of bread. Most likely they had some of the domestic animals and lived mainly on milk and the produce of the chase, together with what they got by stealing. They seem to have practised the art of spinning, though they do not appear to have thought much of clothing. They had no tools or implements made of metal. They had probably a language of their own, which would imply a time when they understood no other and explain why, when they came to a town to do their marketing, they laid down the exact money without uttering a syllable to anybody by way of bargaining for their purchases. They counted by fives and only dealt in the simplest of numbers. They were inordinately fond of music and dancing. They had a marvellously quick sense of hearing, and they were consummate thieves: but their thieving was not systematically resented, as their visits were held to bring luck and prosperity. More powerful races generally feared them as formidable magicians who knew the future and could cause or cure disease as they pleased. The fairies took pains to conceal their names no less than their abodes, and when the name happened to be discovered by strangers the bearer of it usually lost heart and considered himself beaten. Their family relations were of the lowest order: they not only reckoned no fathers, but it may be that, like certain Australian savages recently described by Spencer and Gillen, they had no notion of paternity at all. The stage of civilisation in which fatherhood is of little or no account has left evidence of itself in Celtic literature, as I shall show presently; but the other and lower stage anterior to the idea of fatherhood at all comes into sight only in certain bits of folklore, both Welsh and Irish, to the effect that the fairies were all women and girls. Where could such an idea have originated? Only, it seems to me, among a race once on a level with the native Australians to whom I have alluded, and of whom Frazer of 'the Golden Bough' wrote as follows in last year's 'Fortnightly Review:' 'Thus, in the opinion of these savages, every conception is what we are wont to call an immaculate conception, being brought about by the entrance into the mother of a spirit, apart from any contact with the other sex. Students of folklore have long been familiar with the notions of this sort occurring in the stories of the birth of miraculous personages, but this is the first case on record of a tribe who believe in immaculate conception as the sole cause of the birth of every human being who comes into the world. A people so ignorant of the most elementary of natural processes may well rank at the very bottom of the savage scale.' Those are Dr. Frazer's words, and for a people in that stage of ignorance to have imagined a race all women seems logical and natural enough—but for no other. The direct conclusion, however, to be drawn from this argument is that some race—possibly more than one—which has contributed to the folklore about our fairies, has passed through the stage of ignorance just indicated;

but as an indirect inference one would probably be right in supposing this race to have been no other than the very primitive one which has been exaggerated into fairies. At the same time it must be admitted that they could not have been singular always in this respect among the nations of antiquity, as is amply proved by the prevalence of legends about virgin mothers, to whom Frazer alludes, not to mention certain wild stories such as some of those recorded by the naturalist Pliny concerning certain kinds of animals.

Some help to make out the real history of the Little People may be derived from the names given them, of which the most common in Welsh is that of *y Tylwyth Teg* or the Fair Family. But the word *cor*, 'a dwarf,' feminine *corres*, is also applied to them; and in Breton we have the same word with such derivatives as *korrik*, 'a fairy, a wee little wizard or sorcerer,' with a feminine *korrigan* or *korrigez*, analogously meaning a she-fairy or a diminutive witch. From *cor* we have in Welsh the name of a people called the Corannians figuring in a story in the fourteenth-century manuscript of the Red Book of Hergest. There one learns that the Corannians were such consummate magicians that they could hear every word that reached the wind, as it is put; so they could not be harmed. The name Corannians of those fairies has suggested to Welsh writers a similar explanation of the name of a real people of ancient Britain. I refer to the *Coritani*, whom Ptolemy located, roughly speaking, between the river Trent and Norfolk, assigning to them the two towns of *Lindum*, Lincoln, and *Ratæ*, supposed to have been approximately where Leicester now stands. It looks as if all invaders from the Continent had avoided the coast from Norfolk up to the neighbourhood of the Humber, for the good reason, probably, that it afforded very few inviting landing-places. So here presumably the ancient inhabitants may have survived in sufficient numbers to have been called by their neighbours of a different race 'the dwarfs' or *Coritani*, as late as Ptolemy's time in the second century. This harmonises with the fact that the Coritani are not mentioned as doing anything, all political initiative having long before probably passed out of their hands into those of a more powerful race. How far inland the Coritanian territory extended it is impossible to say, but it may have embraced the northern half of Northamptonshire, where we have a place-name *Pytchley*, from an earlier *Pihtes léa*, meaning 'The Pict's Meadow,' or else the meadow of a man called Pict. At all events, their country took in the fen district containing Croyland, where towards the end of the seventh century St. Guthlac set up his cell on the side of an ancient tumulus and was disturbed by demons that talked Welsh. Certain portions of the Coritanian country offered, as one may infer, special advantages as a home for retreating nationalities: witness as late as the eleventh century the resistance offered by Hereward in the Isle of Ely to the Norman Conqueror and his mail-clad warriors.

In reasoning backwards from the stories about the Little People to a race in some respects on a level with Australian savages, we come probably in contact with one of the very earliest populations of these islands. It is needless to say that we have no data to ascertain how long that occupation may have been uncontested, if at all, or what progress was made in the course of it: perhaps archæology will be able some day to help us to form a guess on that subject. But the question more immediately pressing for answer is, with what race outside Wales may one compare or identify the ancient stock caricatured in Welsh fairy tales? Now, in the lowlands of Scotland, together with the Orkneys and Shetlands, the place of our fairies is to some extent taken by the Picts, or, as they are there colloquially called, 'the Pechts.' My information about the Pechts comes mostly from recent writings on the subject by Mr. David MacRitchie, of Edinburgh, from whom one learns, among other things, that certain underground—or partially underground—habitations in Scotland are ascribed to the Pechts. Now one kind of these Pechts' dwellings appear from the outside like hillocks covered with grass, so as presumably not to attract attention, an object which was further helped by making the entrance very low and as inconspicuous as possible. But one of the most remarkable things about them is the fact that the cells or apartments into which they are divided are frequently so small that their inmates

must have been of very short stature, like our Welsh fairies. Thus, though there appears to be no reason for regarding the northern Picts themselves as an under-sized race, there must have been a people of that description in their country. Perhaps archæologists may succeed in classifying the ancient habitations in the North accordingly: that is, to tell us what class of them were built by the Picts and what by the Little People whom they may be supposed to have found in possession of that part of our island.

In Ireland and the Highlands of Scotland the fairies derive their more usual appellations from a word *síd* or *síth* (genitive *síde*), which may perhaps be akin to the Latin *sēdes* and have meant a seat, settlement, or station; but whatever its exact meaning may have originally been, it came to be applied to the hillocks or mounds within which the Little People made their abodes. Thus *Aes Síde* as a name for the fairies may be rendered by mound people or hill folk; *fer síde*, 'a fairy man,' by a mound man; and *ben síde* by a mound woman or banshee. They were also called simply *síde*, which would seem to be an adjective closely allied with the simpler word *síd*.

But to leave this question of their names, let me direct your attention for a moment to one of the most famous kings of the fairies of ancient Erin: he was called Mider of Brí Léith, said to be a hill to the west of Ardagh, in the present county of Longford. There he had his mound, to which he once carried the queen of Eochaid Airem, monarch of Ireland. It was some time before Eochaid could discover what had become of her, and he ordered Dalán, his druid, to find it out. So the druid, when he had been unsuccessful for a whole year, prepared four twigs of yew and wrote on them in Ogam. Then it was revealed to him through his keys of seership and through the Ogam writing, that the queen was in the *síd* of Brí Léith, having been taken thither by Mider. By this we are probably to understand that the druid sent forth the Ogam twigs as letters of enquiry to other druids in different parts of the country; but in any case he was at last successful, and his king hurried at the head of an army to Brí Léith, where they began in earnest to demolish Mider's mound. At this Mider was so frightened that he sent the queen forth to her husband, who then departed, leaving the fairies to digest their wrath; for it is characteristic of them that they did not fight, but bided their time for revenge, which in this case did not come till long after Eochaid's day. Now, with regard to the fairy king, one is not told, so far as I can call to mind, that he was a dwarf, but the dwarfs were not far off; for we read of an Irish satirist who is represented as notorious for his stinginess, and who, to emphasise the description of his inhospitable habits, is said to have taken from Mider three of his dwarfs and stationed them around his own house, in order that their truculent looks and rude words might repel any of the men of Erin who might come seeking hospitality or bringing any other inconvenient request. The word used for dwarf in this story is *corr*, which is usually the Irish for a crane or heron, but here, and in some other instances, which I cannot now discuss, it seems to have been identical with the Brythonic *cor*, 'a dwarf.' It is remarkable, moreover, that the rôle assigned to the three Irish *corrs* is much the same as that of the dwarf of Edern son of Nudd, in the Welsh story of *Geraint and Enid* and Chrétien de Troies' *Erec*, which characterises him as *fel et de put'eire*, 'treacherous and of an evil kind.'

By way of summarising these notes on the Mound Folk I may say that I should regard them as isolated and wretched remnants of a widely spread race possessing no political significance whatsoever. But, with the inconsistency characteristic of everything connected with the fairies, one has on the other hand to admit, that this strange people seems to have exercised on the Celts—probably on other races as well—a sort of permanent spell of mysteriousness and awe stretching to the verge of adoration. In fact, Irish literature states that the pagan tribes of Erin before the advent of St. Patrick used to worship the *síde* or the fairies. Lastly the Celt's faculty of exaggeration, combined with his incapacity to comprehend the weird and uncanny population of the mounds and caves of his country, has enabled him, in one way or another, to bequeath to the great literatures of Western Europe a motley train of dwarfs and little people, a whole world of wizardry, and a vast wealth of utopianism. If you subtracted from English

literature, for example, all that has been contributed to its vast stores from this native source, you would find that you left a wide and unwelcome void.

But the question must present itself sooner or later, with what race outside these islands we are to compare or identify our mound-dwellers. I am not prepared to answer, and I am disposed to ask our archæologists what they think. In the meantime, however, I may say that there are several considerations which would impel me to think of the Lapps of the North of Europe. But even supposing an identity of origin could be made out as between our ancient mound-inhabiting race and the Lapps, which, I am told, is craniologically impossible, it would remain still doubtful whether we could expect any linguistic help from Lapland. The Lapps now speak a language belonging to the Ugro-Finnic family, but the Lapps are not of the same race as the Finns; so it is possible that the Lapps have adopted a Finnish language and that they did so too late for their present language to help us with regard to any of our linguistic difficulties. One of these lies in our topography: take for instance only the names of our rivers and brooks—there is probably no county in the kingdom that would be too small to supply a dozen or two which would baffle the cleverest Aryan etymologist you could invite to explain them; and why? Because they belong in all probability to a non-Celtic, non-Aryan language of some race that had early possession of our islands. Nevertheless it is very desirable that we should have full lists of such names, so as to see which of them recur and where. It is a subject deserving the attention of this Section of the British Association.

We have now loitered long enough in the gloom of the Pecht's house: let us leave the glamour of the fairies and see whether any other race has had a footing in these islands before the coming of the Celts. In August 1891 Professor Sayce and I spent some fine days together in Kerry and other parts of the south-west of Ireland. He was then full of his visits to North Africa, and he repeatedly assured me that, if a number of Berbers from the mountains had been transferred to a village in Kerry and clad as Irishmen, he would not have been able to tell them by their looks from native Irishmen such as we saw in the course of our excursions. This seemed to me at the time all the more remarkable as his reference was to fairly tall, blue-eyed persons whose hair was rather brown than black. Evidence to the same effect might now be cited in detail from Professor Haddon and his friends' researches among the population of the Arran Islands in Galway Bay. Such is one side of the question which I have in my mind: the other side consists of the fact that the Celtic languages of to-day have been subjected to some disturbing influence which has made their syntax unlike that of the other Aryan languages. I have long been of opinion that the racial interpretation of that fact must be, that the Celts of our islands have assimilated another race using a language of its own in which the syntactical peculiarities of Neo-Celtic had their origin: in fact that some such race clothed its idioms in the vocabulary which it acquired from the Celts. The problem then was to correlate those two facts. I am happy to say this has now been undertaken from the language point of view by Professor J. Morris Jones, of the University College of North Wales. The results have been made public in a book on *The Welsh People* recently published by Mr. Fisher Unwin. The paper is entitled 'Pre-Celtic Syntax in Insular Celtic,' and the languages which have therein been compared with Celtic are old Egyptian and certain dialects of Berber. It is all so recent that we have as yet had no criticism, but the reasoning is so sound and the arguments are of so cumulative a nature, that I see no reason to anticipate that the professor's conclusions are in any danger of being overthrown.

At the close of his linguistic argument, Professor Morris Jones quotes a French authority to the effect, that, when a Berber king dies or is deposed, which seems to happen often enough, it is not his son that is called to succeed him, but the son of his sister, as appears to have been usual among certain ancient peoples of this country; but of this more anon. In the next place my attention has been called by Professor Sayce to the fact that ancient Egyptian monuments represent the Libyans of North Africa with their bodies tattooed, and that even now some of the Touaregs and Kabyles do the same. These indications help one to group

the ancient peoples of the British Isles to whose influence we are to ascribe the non-Aryan features of Neo-Celtic. In the first place one cannot avoid fixing on the Picts, who were so called because of their habit of tattooing themselves. For as to that fact there seems to be no room for doubt, and Mr. Nicholson justly lays stress on the testimony of the Greek historian Herodian, who lived in the time of Severus, and wrote about the latter's expedition against the natives of North Britain a long time before the term *Picti* appears in literature. For Herodian, after saying that they went naked, writes about them to the following effect: 'They puncture their bodies with coloured designs and the figures of animals of all kinds, and it is for this reason that they do not wear clothes, lest one should not behold the designs on their bodies.' This is borne out by the names by which the Picts have been known to the Celts. That of *Pict* is itself in point, and I shall have something to say of it presently; but one of the other names was in Irish *Cruithni*, and in Welsh we have its etymological equivalent in *Prydyn* or *Prydain*. These vocables are derived respectively from Irish *cruth* and Welsh *pryd*, both meaning shape, form, or figure, and it is an old surmise that the Picts were called by those names in allusion to the animal forms pricked on their bodies, as described by Herodian and others. The earlier attested of these two names may be said to be Prydyn or Prydain, which the Welsh used to give in the Middle Ages to the Picts and the Pictland of the North, while the term *Ynys Prydain* was retained for Great Britain as a whole, the literal meaning being the Island of the Picts: that is the only name which we have in Welsh to this day for this island in which we live—*Ynys Prydain*, 'The Picts' Island.' Now one detects this word Prydain in effect in the Greek Πρετανικαὶ Νῆσοι given collectively to all the British Isles by ancient authors. It may be rendered the Pictish Islands, but a confusion seems to have set in pretty early with the name of the Brittanni or Brittones of South Britain: that is to say, *Pretanic*, 'Pictish,' became *Brittannic* or British; and this is, historically speaking, the only known justification we have for including Ireland in the comprehensive term 'The British Isles,' to which Irishmen are sometimes found jocularly to object.

In the next place may be mentioned the Tuatha Dé Danann of Irish legend, who cannot always be distinguished from the Picts, as pointed out by Mr. MacRitchie. The tradition about them is, that, when they were overcome in war by Mil and his Milesians, they gave up their life above ground and retired into the hills like the fairies, a story of little more value than that of the extermination of the Picts of Scotland. In both countries doubtless the more ancient race survived to amalgamate with its conquerors. There was probably some amount of amalgamation between the Tuatha Dé Danann or the Picts and the Little Moundsmen; but it is necessary not to confound them. The Tuatha shared with the Little People a great reputation for magic; but they differed from them in not being dwarfs or of a swarthy complexion: they are usually represented as fair. In the case of Mider, the fairy king, who comes in some respects near the description of the heroes of the Tuatha Dé Danann, it is to be noticed that he was a wizard, not a warrior.

Guided by the kinship of the name of the Tuatha Dé *Danann* on the Irish side of the sea and that of the Sons of *Dôn* on this side, I may mention that the Mabinogion place the Sons of Dôn on the seaboard of North Wales, in what is now Carnarvonshire: more precisely their country was the region extending from the mountains to the sea, especially opposite Anglesey. In that district we have at least three great prehistoric sites all on the coast. First comes the great stronghold on the top of Penmaen Mawr; then we have the huge mound of Dinas Dinlle, eaten into at present by the sea south-west of the western mouth of the Menai Straits; and lastly there is the extensive fortification of Tre'r Ceiri, overlooking Dinlle from the heights of the Eifl. By its position Tre'r Ceiri belonged to the Sons of Dôn, and by its name it seems to me to belong to the Picts, which comes, I believe, to the same thing. Now the name Tre'r Ceiri means the town of the Keiri, and the Welsh word *ceiri* is used in the district in the sense of persons who are boastful and ostentatious, especially in the matter of personal appearance and fine clothing. It is sometimes also confounded with *cewri*,

'giants,' but in the name of Tre'r Ceiri it doubtless wafts down to us an echo of the personal conceit of the ancient Picts with their skins tattooed with decorative pictures; and Welsh literature supplies a parallel to the name *Ynys Prydain* in one which is found written *Ynys y Ceûri*, both of which may be rendered equally the Island of the Picts, but more literally perhaps some such rendering as 'the Island of the Fine Men' would more nearly hit the mark. Lastly, with the Sons of Dôn must probably be classed the other peoples of the Mabinogion, such as the families of Llyr, and of Pwyll and Rhiannon.

All these peoples of Britain and Ireland were warlike, and such, so far as one can see, that the Celts, who arrived later, might with them form one mixed people with a mixed language, such as Professor Morris Jones has been helping to account for.

Let us now see for a moment how what we read of the state of society implied in the stories of the Mabinogion will fit into the hypothesis which I have roughly sketched. In the first place I ought to explain that the four stories of the Mabinogion were probably put together originally in the Goidelic of Wales, before they assumed a Brythonic dress. Further, in the form in which we know them, they have passed through the hands of a scribe or editor living in Norman times, who does not always appear to have understood the text on which he was operating. To make out, therefore, what the original Mabinogion meant, one has every now and then to read, so to say, between the lines. Let us take for example the Mabinogi called after Branwen, daughter of Llyr. She was sister to Brân, king of Prydain, and to Manawyddan, his brother: she was given to wife to an Irish king named Matholwch, by whom she had a son called Gwern. In Ireland, however, she was, after a time disgraced, and served in somewhat the same way as the heroine of the Gudrun Lay; but in the course of the time which she spent in a menial position, doing the baking for the Court and having a box on the ear administered to her daily by the cook, she succeeded in rearing a starling, which one day carried a letter from her to her brother Brân at Harlech. When the latter realised his sister's position of disgrace, he headed an expedition to Ireland, whereupon Matholwch tried to appease him by making a concession, which was, that he should deliver his kingdom to the boy Gwern. Now the question is, wherein did the concession consist? The redactor of the Mabinogi could, seemingly, not have answered, and he has not made it the easier for any one else to answer. In the first place, instead of calling Gwern son of Matholwch, he should have called him Gwern son of Branwen, after his mother, for the key to the sense is, that, in a society which reckoned birth alone, Gwern was not recognised as any relation to Matholwch at all, whereas, being Brân's sister's son, he was Brân's rightful heir. No such idea, however, was present to the mind of a twelfth-century scribe, nor could it be expected.

Let us now turn to Irish literature, to wit, to one of the many stories associated with the hero Cúchulainn. He belonged to Ulster, and whatever other race may have been in that part of Ireland, there were Picts there: as a matter of fact Pictish communities survived there in historical times. Now Cúchulainn was not wholly of the same race as the Ultonians around him, for he and his father are sharply marked off from all the other Ultonians as being free from the periodical illness connected with what has been called the couvade, to which the other adult braves of Ulster succumbed for a time every year. Then I may mention that Cúchulainn's baby name was *Setanta Beg*, or the Little Setantian, which points to the country whence Cúchulainn's father had probably come, namely the district where Ptolemy mentions a harbour of the Setantii, somewhere near the mouth of the Ribble, in what is now Lancashire. At the time alluded to in the story I have in view, Cúchulainn was young and single, but he was even then a great warrior, and the ladies of Ulster readily fell in love with him; so one day the nobles of that country met to consider what was to be done, and they agreed that Cúchulainn would cause them less anxiety if they could find him a woman who should be his fitting and special consort. At the same time also that they feared he might die young, they were desirous that he should leave an heir, 'for,' as it is put in the story, 'they knew that it was from himself his rebirth would be.'

The Ulster men had a belief, you see, in the return of the heroes of previous generations to be born again; but we have here also two social systems face to face. According to the one to which Cúchulainn as a Celt belonged, it was requisite that he should be the father of recognised offspring, for it was only in the person of one of them or of their descendants that he was to be expected back. The story reads as if the distinction was exceptional, and as if the prevailing state of things was wives more or less in common, with descent reckoned according to birth alone. Such is my impression of the picture of the society forming the background to the state of things implied by the conversation attributed to the noblemen of Ulster. Here again one experiences difficulties arising from the fact, that the stories have been built up in the form in which we know them by men who worked from the Christian point of view; and it is only by scrutinising, as it were, the chinks and cracks that you can faintly realise what the original structure was like.

Among other aids to that end one must reckon the instances of men being designated with the help of the mother's name, not the father's: witness that of the king of Ulster in Cúchulainn's time, namely Conchobar mac Nessa, that is to say, Conor, son of a mother named Nessa; similarly in Wales with Gwydion son of Dôn. Further we have the help of a considerable number of ancient inscriptions, roughly guessed to date from the fifth or the sixth century of our era, and commemorating persons traced back to a family group of the kind, perhaps, which Cæsar mentions in the fourteenth chapter of his fifth book. Within these groups the wives were, according to him, in common (*inter se communes*). Take for instance an inscription from the barony of Corcaguiny in Kerry, which commemorates a man described as 'Mac Erce, son of *Muco Dovvinias*,' where *Muco Dovvinias* means the clan or family group of *Dovvinis* or *Dubin* (genitive *Duibne*), the ancestress after whom Corcaguiny is called *Corco-Duibne* in Medieval Irish. We have the same formula in the rest of Ireland, including Ulster, where as yet very few Ogams have been found at all. It occurs in South Wales and in Devonshire, and also on the Ogam stone found at Silchester in Hampshire. The same kind of family group is evidenced also by an inscription at St. Ninian's, in Galloway; and, to go further back—perhaps a good deal further back—we come to the bronze discovered not long ago at Colchester, and dating from the time of the Emperor Alexander Severus, who reigned from 222 to 235. This is a votive tablet to a god Mars Medocius, by a Caledonian Pict, who gives his name as Lossio Veda, and describes himself further as *Nepos Vepogeni Caledo.* He alludes to no father, and *Nepos Vepogeni* is probably to be rendered Vepogen's sister's son. At any rate, the Irish word corresponding etymologically to the Latin *nepos* has that sense in Irish; and, so far as I know, it has never been found meaning a nephew in the sense of brother's son. That may serve as an instance how the ideas of another race penetrated the fabric of Goidelic society; for here we must suppose a time to have come when there was no longer any occasion for a word meaning a brother's son, which, of course, there never was in the non-Celtic society which ranked men and women according to their birth alone.

Now this Caledonian Pict was not exceptional among his kinsmen, for they succeeded in observing a good deal of silence concerning their fathers down, one may say, to the 12th century. It is historical that the king of the northern Picts was not wont to be the son of the previous king. In short, when the Celtic elements there proved strong enough to ensure that the son of a previous king should succeed, a split usually took place, the purer Picts being led by the rule of succession by birth to set up a king of their own. The fact is not so well known that the same succession prevailed also some time or other at Tara in Ireland: it is proved by a singular piece of indirect evidence, the existence of a tragic story to explain why 'no son should ever take the lordship of Tara after his father, unless some one came between them.' The last clause is due, I should say, to somebody who could not understand such a prohibition based on the ancient rule that a man's heir was his sister's son. This would be, according to Irish legend, in the lifetime of Conor mac Nessa.

It is curious to notice how the stories about the Pictish *ménage* seem to have

puzzled ancient authors. I will cite only one instance, to wit, from Golding's 16th century translation of what then passed as the production of Solinus, and what may pass now, even according to Mommsen, as quite old enough for my present purpose. It runs thus: 'Next come the Iles called *Hebudes*, five in number, the inhabiters whereof know not what corne meaneth, but liue onely by fishe and milke. They are all vnder the gouernment of one King. For as manie of them as bee, they are seuered but with a narrowe groope one from another. The King hath nothing of hys own, but taketh of euery mans. He is bounde to equitie by certaine lawes: and least he may start from right through couetousnesse, he learneth Justice by pouertie, as who may have nothing proper or peculiar to himselfe, but is found at the charges of the Realme. Hee is not suffered to haue anie woman to himselfe, but whomsoeuer he hath minde vnto, he borroweth her for a tyme, and so others by turnes. Wherby it commeth to passe that he hath neither desire nor hope of issue.'

The man who wrote in that way presumably failed to see that the king was not subject to any special hardship as compared with the other men in his kingdom, where none of them had any offspring that he could individually call his own. This, be it noticed, refers to the Hebrides, not, as sometimes happens with such references, to the more distant island of Thule, where there was also a king, as any reader of Faust will tell us.

We now come to the Celts, and begin with Pliny's version of Cæsar's words about the division of Gaul into three parts, as follows: *Gallia omnis Comata uno nomine appellata in tria populorum genera dividitur, amnibus maxime distincta. A Scalde ad Sequanam Belgica, ab eo ad Garunnam Celtica eademque Lugdunensis, inde ad Pyrenæi montis excursum Aquitanica, Aremorica antea dicta.* We may for the present dismiss the third or Aquitanic Gaul from our minds; but Belgic and Celtican Gaul may be taken as representing the two sets of Celts of our own islands. The Belgic Gauls began last to come to this country, and their advent seems to fall between the visits of Pytheas and Julius Cæsar: that is, roughly speaking, between the middle of the fourth century and that of the first century B.C. In this country they came to be known collectively as Brittanni or Brittones, the linguistic ancestors of the peoples who have spoken Brythonic or the *Lingua Brittannica*, such as the Welsh, the Cornish, and the Strathclyde Britons. As to the other Celts, it is much harder to say when or whence exactly they came—I mean the linguistic ancestors of the Gaels of Ireland, Man, and Scotland, that is to say, the peoples whose language has been Goidelic. Some scholars are of opinion that there were no Goidelic-speaking peoples in Britain till some such came here from Ireland on sundry occasions, beginning with the second century, in the time of the Roman occupation; but how the Goidels would be supposed by them to have reached Ireland I do not exactly know. My own notion is that the bulk of them reached that country by way of Britain, and that they arrived in Britain, like the Belgic Gauls later, from the nearest parts of the Continent; for this would be previous to the appearance of the Belgic Gauls on the western seaboard of Europe: that is to say, at a time when Celtica extended not merely to the Seine, but to the Scheldt or to the Rhine, if not even further. Then as to the time of the coming of the ancestors of the Goidels, it has been supposed coincident with a period of great movements among the Celts of the Continent, in particular the movements which resulted, among other things, in some of them reaching the shores of the Mediterranean and penetrating to the heart of the Iberic peninsula. Perhaps one would not be far wrong in fixing on the seventh and the sixth centuries B.C. as covering the time of the coming of the earlier Celts to our shores.

In Britain I should suppose these earlier hordes of Celts to have conquered most of the southern half of the island; and the Brythonic Celts, when they arrived, may have overrun much the same area, pushing the Goidelic Celts more and more towards the west. Under that pressure it is natural to suppose that some of the latter made their way to Ireland, but it is quite possible that their emigration thither had begun before. Some time or other previous to the Roman occupation the Brythonic people of the Ordovices seem to have penetrated to the

sea between the rivers Dovey and Mawddach, displacing probably some Goidels who may have gone to the opposite coasts of Ireland; but in Irish story more traces appear of invasions on the part of the Dumnonii, who possessed the coast between Galloway and Argyle. These were so situated as to be able to assail Ireland both in front and from behind, and this is countenanced to some extent by Irish topography, not to mention the long legends extant as to great wars in the west of Ireland between the Tuatha Dé Danann and invaders including the Fir Domnann. I suspect also that it was the country of these northern Dumnonians which was originally meant by Lochlinn, a name interpreted later to mean Norway.

Such are some of the faint traces of the Goidelic invasions of Ireland from Britain, but it is possible—perhaps probable—that Ireland received settlers on its southern coast from the north-west of Gaul at a comparatively late period, at the time, let us say, when Cæsar was engaged in crushing the Veneti and the Aremoric League. This has been suggested to me by the name of the Usdiæ, which probably survives in the first syllable of *Ossory*, denoting a tract of country now, roughly speaking, covered by the county of Kilkenny, but which may have been considerably larger before the Déisi took possession of the baronies of the two Decies and other districts now constituting the county of Waterford, not to mention possible encroachments on the part of Munster on a boundary which seems to have been sometimes contested. Now the Continental name which invites comparison with that of the Usdiæ is that of the Ostiæi, who in the time of Pytheas appear to have occupied the north-western end of what afterwards came to be called Brittany; they were also called Ostiones, and more commonly Osismi. I see no reason to suppose that the ships of the Aremoric League could not make the voyage from Brittany to the principal landing-places on the south of Ireland from the Harbour of Cork to that of Waterford, and I gather from Ptolemy's Geography that Ireland was relatively better known on the Continent than Britain, although the latter had in a manner been long connected with the Roman world. This I should explain somewhat as follows:—Cæsar, who knew very little about the west of Britain and less about Ireland, says that in his time the great druidic centre of Gaul was in the country of the Carnutes, somewhere, let us say, near the site of the present town of Chartres, that druidism had been introduced from Britain to Gaul, and that those who wished to understand it had to go to Britain to study. The authors of antiquity tell us otherwise nothing about druids in Britain except that Tacitus speaks of such in the Annals, in his well-known passage as to Suetonius Paulinus landing with his troops in Anglesey and the scene of slaughter which ensued. Indeed, one may go further and say that there is no proof that any Belgic or Brythonic people ever had druids: they belonged to the Celtican Gauls and the Goidelicising Celts of Britain and Ireland, who had probably accepted the institution from the Pictish race. At any rate it is significant that the Life of St. Columba introduces the reader to a genuine druid at the court of the Pictish king, near Inverness, where, as well as on Loch Ness, the saint had to contend with him. In any case, it is highly probable that druidism was no less a living institution in Ireland than in the Goidelic and Pictish parts of Britain. Presumably it was more so, and it may be conjectured that Gaulish students of druidism visited Ireland no less than Britain; also, *vice versa*, that Irish druids paid visits to the Celtican part of Gaul where druidism flourished on the Continent, and in a word that there was regular intercourse between Gaul and the south of Ireland. If the druids of Ireland, who, among other rôles, played that of schoolmasters and teachers in that country, travelled to Celtica, they must have spread on the Continent some information about their native country, while generations of them cannot have returned to Ireland, with their druidic pupils, without bringing with them some of the arts of civilised life as understood in Gaul: among these one must rank very decidedly the art of writing, which the druids practised. Now you know the usual account given of the ordinary Latin for Ireland, namely *Hibernia*—to wit, that it was suggested by such native names as that of one of the greatest tribes of that country, namely the Ἰούερνοι

or *Iverni,* and that it had its *v* ousted when Latin began about the 4th century to write *b* for *v,* and that an *h* was then prefixed to make the word *Hibernia* properly connote the wintry climate which our sister island had always been supposed to enjoy. But now comes the question, where did Pomponius Mela, who flourished about the middle of the first century, get his *Iuverna,* which Juvenal also used? Doubtless from a druid like Dalán, or some other educated native of Ireland; for what the editors print as *Iuverna, Iuuerna,* or *Juverna,* would appear in ancient manuscripts as *IVVERNA* or *iuuerna,* in which the first two syllables are spelt correctly with *v v* according to a system of spelling well known in Ogmic writing centuries later. But a particular system of spelling seems to me to imply writing, and thus one is encouraged to think that the Ogam alphabet may have been invented no later than the first century, in the intercourse I have conjectured to have been going on between the north-west of Gaul and the south of Ireland, where the majority of Ogam inscriptions are now found. But what has archæology to say on the question of such intercourse?

After this digression I come back to the two main streams of Celtic immigration, from the same parts of the Continent in two different periods of time. The later of these introduced the *Lingua Brittannica,* which was practically a dialect of old Gaulish; but the affinities of the other Celtic language of these islands, the Goidelic, are not so easy to determine. I have long thought that I can identify traces of it on the Continent, and that its principal home was in the region which Pliny called Celtica, between the Garonne and the Seine. I ventured accordingly to call it *Celtican,* as the simpler word *Celtic* had already been wedded to a wider signification. Since I did so the existence of that language has been placed beyond doubt by the discovery of fragments of a calendar engraved on bronze tablets. This find was made about the end of 1897 at a place called Coligny, in the department of the Ain, and the pieces are now in the museum at Lyons. It is difficult to say for certain whether Coligny is within the territory once occupied by the Sequani, or else by the Ambarri, a people subject to the Ædui, who were the rivals of the Sequani and Arverni. The name of the Sequani would seem to have belonged to the Celtican language, and Mr. Nicholson, in his interpretation of the calendar, has ventured in this instance to call it Sequanian. But two inscriptions in what appears to be the same language have come to light also at a place called Rom, in the Deux Sèvres and on the Roman road from Poitiers to Saintes. This Celtican language is to be carefully distinguished from Gaulish, but it is not exactly what I expected it to be: it is better. For several of the phonetic changes characteristic of Goidelic had not taken place in Celtican. Among other things it preserves intact the Aryan consonant *p,* which has since mostly disappeared in Goidelic, as it had even then in Gaulish. This greater conservatism of Celtican enables one to refer to it the national appellation of the people of the region in question, namely that of the *Pictones,* from which it is impossible to sever the name of the Picts of Britain and Ireland, who are found also called *Pictones* and *Pictanei.* Here I may mention that Mr. Nicholson calls attention to instances of tattooing on some of the faces on ancient coins belonging to Poitou and other parts of western France. In the light of the names here in question one sees that *pictos* was a Celtican word of the same etymology, and approximately, doubtless, of the same meaning, as the Latin word *pictus,* that the Celticans had applied it at an early date to the Picts on account of their habit of tattooing themselves, and that the Picts had accepted it (with its derivative *Pictones*) so generally that by the time when the Norsemen arrived in the North of Scotland, it was the name which the natives gave them as that by which they called themselves. That is practically proved by the Norsemen calling Caithness and Sutherland *Petta-land* or the Land of the Picts, and the sea washing its northern shore *Pettalands fiorth,* which survives modified into *Pentland Firth.*

Another Celtican word of great interest here has by a mere chance come down in a High German manuscript written before the year 814: it is *Chortonicum,* and it occurs among a number of geographical names, several of which refer to Gaul,

so that Chortonicum may very well have meant the country of the Pictones. At all events, the great German philologist Pott at once saw that it was to be explained by reference to the word Cruithne, 'a Pict,' with which it decidedly goes as distinguished from its Brythonic equivalent *Prydyn* (or the older *Priten*) with an initial *p*. The Celtican form originally meant was some such vocable as Qurtonico-n, with the *qu* which was usual in Celtican and early Goidelic, where it formed, in fact, one of the most conspicuous distinctions between those languages and Brythonic or Gaulish, in which *qu* had been changed into *p*.

My remarks have again run into tiresome details, but it is only by attending to such small points that one can hope to force language to yield us any information in the matter of ethnology. It may perhaps help in some measure if I sum up what I have been trying to say, thus:

The first race we have found in possession of the British Isles consisted of a small swarthy population of mound-dwellers, of an unwarlike disposition, much given to magic and wizardry, and living underground: its attributes have been exaggerated or otherwise distorted in the evolution of the Little People of our fairy tales.

The next race consisted of a blue-eyed people, taller and blonder, who tattooed themselves and fought battles. These tattooed or Pictish people made the Mound Folk their slaves, and in the long run their language may be supposed to have been modified by habits of speech introduced by those slaves of theirs from their own idiom. The affinities of these Picts may be called Libyan, and possibly Iberian.

Next came the Celts in two great waves of immigration, the first of which may have arrived as early as the 7th century before our era, and consisted of the real ancestors of some of our Goidels of the Milesian stock, and the linguistic ancestors of all the peoples who have spoken Goidelic. That language may be defined as Celtican so modified by the idioms of the population, which the earlier Celts found in possession, that its syntax is no longer Aryan.

Then, about the third century B.C., came from Belgica the linguistic ancestors of the peoples who have spoken Brythonic; but most of our modern Brythons are to be regarded as descended from Goidels who adopted Brythonic speech, and in so doing brought into that language their Goidelic idioms, with the result that the syntax of insular Brythonic is no less non-Aryan than that of Goidelic, as may be readily seen by comparing the thoroughly Aryan structure of the few sentences of old Gaulish extant.

Those are the races which have been inferred in the course of these remarks, in which I have proceeded on the principle that each successive band of conquerors has its race, language, and institutions eventually more or less modified by contact with the race, language, and institutions of those whom it has conquered. That looks simple enough when stated so, but the result which we get proves complicate. At all events I have endeavoured to substitute for the rabble of divinities and demons, of fairies and phantoms that disport themselves at large in Celtic legend, a possible succession of peoples, to each of which should be ascribed its own proper attributes. But that will only be possible if we can enlist the kindly aid of the Muse of Archæology.

The following Papers and Reports were read:—

1. *Some Implements of the Natives of Tasmania.* *By* J. PAXTON MOIR.

The author gives an account of diggings in native camping grounds in Tasmania, and of the rude underground stone implements found there, comprising hand-axes, skinning knives, &c., and especially certain tools of finer make, concave scrapers, and groovers.

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2. *The Stone Age in Tasmania as related to the History of Civilisation.* *By* E. B. Tylor, *F.R.S.*

This paper, with special reference to the previous one, discussed the Palæolithic, or unground Stone Age in Tasmania, which lasted till superseded by the English colonisation early in this century, passing directly into the Iron Age without the intervention of a Neolithic, or ground Stone Age.

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3. *Report on Mental and Physical Deviations of Children in Schools.* See Reports, p. 461.

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4. *Report on the Silchester Excavation.*—See Reports, p. 466.

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5. *Writing in Prehistoric Greece.* *By* Arthur J. Evans, *M.A., F.S.A*

(1) *Clay Documents with Hieroglyphic or Conventionalised Pictographic Script from the Palace of Knossos.*

The discovery originally announced by the author in 1894, in this Section,[1] of the existence in prehistoric Crete of a system of conventionalised pictographic or hieroglyphic writing had received an extraordinary corroboration and supplement from his recent excavations in the Mycenæan Palace of Knossos. The first indications had been supplied by groups of signs engraved on early seal-stones, and by its nature the evidence was limited. But in the great prehistoric building now partially explored at Knossos, the latest elements of which can hardly be brought down later than the thirteenth century B.C., there came to light a series of deposits of clay archives inscribed both with hieroglyphic and a new system of linear writing.

Those of the hieroglyphic class, though apparently contemporary with the other, were less numerous and were found in a separate magazine. They were in the form of square and three-sided bars, perforated at the end, clay 'labels' also perforated, in shape like bivalve shells, and sealings of clay which also presented impressions of signets with characters of the same conventionalised pictographic class. The graffito characters of the clay bars, &c., gave more linearised versions of the fuller representations of the engraved seals, and thus illustrated a step in the formation of letters. The tablets showed various new forms of hieroglyphs not as yet found on the signets, raising the Cretan series to over a hundred. The pictographic signs might be said to form an illustrated history of Cretan culture in Mycenæan times. Among new characters might be mentioned an eight-stringed lyre, carpenter's tools such as a kind of plane and perhaps a level, dogs' heads, bees, a glove-like object perhaps not unconnected with bee-keeping, and apparently olive sprays. The obviously 'ideographic' or 'determinative' character of some of the hieroglyphs gives a clue to the meaning of many of the tablets. Ships, ploughs and ox-heads, vessels filled with grain, and the Egyptian palace sign speak for themselves. A boustrophêdon arrangement of the characters is often traceable. Many of these clay records are accounts, as is shown by the presence of various numeral signs, the ciphers never exceeding eight in a group. But the form of numeration still presents points of obscurity.

The hieroglyphic script itself shows a certain parallelism with the 'Hittite' inscriptions of Anatolia and Northern Syria. Its beginnings can, however, be traced very far back on Cretan soil, and it unquestionably represents the writing of the indigenous Cretan stock, the Eteocretans of the 'Odyssey.'

[1] *Report Brit. Assoc.* (Oxford), 1894, p. 776.

(2) *Clay Documents inscribed with Linear Script from the Palace of Knossos.*

The great bulk of the clay records discovered in the Palace of Knossos exhibited a linear style of writing fundamentally different from that of the hieroglyphic class, and far ahead of it in development. The tablets are for the most part elongated slips of hand-moulded clay, from two to about seven inches in length, and from half an inch to three inches broad; others, however, are of a squarer form. They present some distant analogy to the Babylonian tablets, and the inscription is divided by horizontal lines. The letters themselves, however, are of a free, upright European character. Some seventy characters seem to have been in common use, and of them about ten show resemblances to the later Greek and the same number to the Cypriote syllabary. About the same number of forms are also common to the hieroglyphic Cretan series. The letters seem to have been for the most part syllabic; lines of division appear between the words, and the writing runs consistently from left to right. The pictorial origin of these letters may be traced in some cases. Thus, we have the human head and neck, the hand, the crossed arms, a bird flying, three or four barred gates, a fence, a high-backed throne, a tree, and a leaf. A certain number are unquestionably ideographic or determinative. Others represent measures and quantities, and are always associated with numerals. A good many of these documents evidently refer to Palace accounts, and a clue to the general purport of the tablet is often supplied by the introduction of a pictorial figure. We thus find chariots and horses, human figures, perhaps slaves, axes, ingots, vases of precious metals, others of clay for various liquids, houses or barns, swine, ears of corn, various kinds of trees and a crocus-like flower, perhaps used for a dye or perfume.

A decimal system of numeration was employed, somewhat resembling the Egyptian. The value theoretically arrived at by the author for the numerals was proved by an addition sum presented by one tablet, the total of which worked out correctly.

The ingots depicted on the tablets resembled a Mycenæan copper ingot from Cyprus and others from Sardinia. They were followed by a balance (the Greek *talanton*) and numerals apparently indicating their value in Mycenæan gold talents. It has thus been possible to make an approximate calculation of their weight. Objects in precious metals represented were identical with some typical tributary offerings of the Keft chieftains on the Theban monuments of Thothmes III.'s time, and tended to show that some of these clay documents went back to the first half of the fifteenth century B.C.

Other tablets, without ciphers or pictorial figures, perhaps refer to contracts or correspondence, such as the contemporary records of Syria and Babylonia. The tablets had been originally contained in coffers of wood, clay, and gypsum, and these in turn secured by clay seals bearing impressions of Mycenæan engraved gems of the finest style. These impressions had in many cases been countermarked with a graffito sign by the controlling official while the clay was still wet, and the back of the clay seal was at the same time endorsed and countersigned with short inscriptions in the same script as that of the tablets. Such legal precautions were quite worthy of the 'Palace of Minos.'

These discoveries not only carry back the existence of written documents on Greek soil some seven centuries before the first known monuments of Greek writing, and five before the earliest Phœnician, but they afford a wholly new standpoint for investigating the origin of the alphabet.

The letter-forms borrowed by the Greeks from the Phœnicians seem to have been influenced by these pre-existing Ægean scripts. The common elements existing in the Phœnician alphabet itself are very noteworthy. Out of twenty-two original letters, some twelve present obvious points of comparison with characters belonging to one or other of the two Cretan scripts, and to these at least four may be added as showing possible affinities. In view of such parallelism, which extends to the meaning as well as the form of the signs, De Rougé's theory of the derivation of the Phœnician letters from remote hieratic Egyptian prototypes must be definitely abandoned. The Phœnician, and with it the Greek, alphabet must

be regarded as a selection from a syllabary belonging to the same generic group as the Cretan. Such a phenomenon on the Syrian coast is perhaps explained by the settlement there in Mycenæan times of an Ægean island race, the Philistines, whose name survives in that of Palestine. Though later Semitised, their biblical names of Kaphtorim and Kerethim, or Cretans, sufficiently record their Ægean origin.

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6. *On the System of Writing in Ancient Egypt. By* F. Ll. Griffith.

Egyptology has now reached a position among the sciences from which it may contribute trustworthy information for the benefit of kindred researches. Egyptian writing consists of Ideographic and Phonetic Elements, the signs serving as —1, Word-signs; 2, Phonograms; 3, Determinatives. The highest development shown is an alphabet, which, however, is never used independently of other signs: it is apparently not acrophonic in origin; it represents consonants and semi-consonants only, vocalisation not being recorded by Egyptian writing. No advance can be detected in the system from the beginning of the historic period to the end, notwithstanding some improvements in practical working which facilitated the use of cursive writing. Phonograms derived from word-signs. The end of the native system was brought about by the gradual adoption of the Greek character —beginning, perhaps, in the second century A.D. If any radical improvement was ever made in the Egyptian form of writing that improvement must have taken place at or after adoption by another people: *e.g.*, some have supposed that our alphabet was derived by the Phœnicians from Egypt; but any such derivations are at present entirely hypothetical.

Although the Egyptian system of writing may not be actually a stage in the history of our alphabet, it throws a strong light on the development of the alphabetic system; and the survival of its pictorial form (for decorative purposes) enables us to recognise the highly ramified connections between the forms and meanings of characters to an extent which is impossible at present in any other system, whether in Mesopotamia, China, or elsewhere.

Results of recent Egyptian philology: Egyptian originally a Semitic language, though its character changed early. The main lines of the grammar being at length established, the materials for a complete dictionary are now being collected and classified.

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7. *Interim Report on Anthropological Teaching.*

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8. *Report on Anthropological Photographs.*—See Reports, p. 568.

FRIDAY, SEPTEMBER 7.

The following Papers were read:—

1. *The Cave of Psychró in Crete. By* D. G. Hogarth.

It has been known for some years that a large cave above the village of Psychró, in the Lasithi district of Crete, was a repository of primitive votive objects in bronze, terra-cotta, &c. As this cave is situated in the eastern flank of the mountain which dominates the site of ancient Lyttos, and is the only important cave known in the neighbourhood, it was conjectured that it was the Lyttian grotto connected with the story of the birth of Zeus in the legend, whose earliest

version is preserved by Hesiod. A thorough exploration of it, undertaken in May and June of the current year, by Mr. D. G. Hogarth, on behalf of the British School at Athens, aided by the Cretan Exploration Fund, has served fully to confirm this view. The cave is double. On the north is a shallow grotto, the upper part of which was cumbered with immense fallen fragments of the roof. The lower part contained deep black earth, partly ransacked by previous diggers. This was thoroughly dug out this year, and when the great blocks had been broken up with blasting powder and removed, the deposit on the higher slope was also searched. The result was the discovery of a rude altar in the middle of the grotto, surrounded by strata of ashes, pottery, and other refuse, among which many votive objects in bronze, terra-cotta, iron, and bone were found, together with fragments of some thirty libation tables in stone, and an immense number of earthenware cups used for depositing offerings. The lowest part of the Upper Grotto was found to be enclosed by a wall partly of rude Cyclopean character, and partly rock-cut; and within this Temenos the untouched strata of deposit ranged from the early Mycenæan Age up to the Geometric period of the ninth century B.C. or thereabout. Only very slight traces were found of later offerings. The earliest votive stratum belongs to the latest period of the pre-Mycenæan Age, that marked by the transition between the 'Kamáraes' fabric of pottery and the earliest Mycenæan lustre-painted ware. But below all is a thick bed of yellow clay, containing scraps of primitive hand-burnished black and brown pottery, mixed with bones of animals. This bed seems to be water-laid, and to be prior to the use of the cave as a sanctuary. Probably, when it was in process of formation, the cave was still a swallow-hole of the lake which once occupied the closed Lasithi basin; but before the Mycenæan period the present outlet had opened, and the plain was dry.

The southern or Lower Grotto falls steeply for some 200 feet to a subterranean pool, out of which rises a forest of stalactite pillars. Traces of a rock-cut stairway remain. Much earth had been thrown down by the diggers of the Upper Grotto, and this was found full of small bronze objects. But chance revealed a more fruitful field, namely, the vertical chinks in the lowest stalactite pillars, a great many of which were found still to contain toy double axes, knife-blades, needles, and other objects in bronze, placed there by dedicators, as in niches. The mud also at the edge of the subterranean pool was rich in similar things, and in statuettes of two types, male and female, and engraved gems. These had probably been washed out of the niches.

The knife-blades and *simulacra* of weapons are probably the offerings of men; the needles and depilatory tweezers of women. The frequent occurrence of the double axe, not only in bronze, but moulded or painted on pottery, found in the cave, leaves no doubt that its patron god was the 'Carian' Zeus of *Labranda*, or the *Labyrinth*, with whom perhaps his mother, the Nature goddess, was associated, and the statuettes probably represent the two deities. Here was the primitive scene of their legend, transferred in classical times to a cave on Mount Ida.

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2. *On the Japanese Gohei and the Ainu Inao.* *By* W. G. ASTON.

The paper illustrates a principle in the history of religion by which the object which is at first simply an offering has a tendency to become conceived of as the embodiment of the God, or even as a distinct and independent deity.

In ancient Japan the offerings to the gods were of the most varied description. Among them were included hemp and bark fibre, together with cloth made from these materials. In later times there was substituted a small quantity of paper made of the same bark fibre and attached to a wand in the form known to us as *gohei*. With the change of form the original character of the *gohei* as offerings was forgotten. They were looked upon as receptacles or embodiments of the God, and honour was paid to them accordingly. At festivals the God descended into the *gohei* on a certain formula being pronounced by the priest. Hypnotic practitioners also used these objects in their séances, the deity who inspired them in

their trances being supposed to enter their body by this channel. There are cases in Japan in which the devotee has gone a step further, and has constituted the object, which was originally an offering, a distinct and independent deity.

The Ainus of Yezo use in their worship whittled sticks called *inao*, which have a general resemblance to an old form of the *gohei*, and are no doubt a cheaper substitute for them. The *inao*, like the *gohei*, are primarily offerings, but in certain cases they receive direct worship as gods, having become in short genuine fetishes. Another link between the *inao* and the *gohei* is provided by certain whittled sticks closely resembling *inao* which were in use in Northern Japan a century ago for striking women with in order to ensure fertility, as in the Roman Lupercalia. Similar sticks after consecration by the Shuite priests were formerly used at Kioto to kindle the household fire afresh on the new year, and so avert possible pestilence.

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3. *The Textile Patterns of the Sea-Dayaks.* *By* Dr. A. C. Haddon, *F.R.S.*

The Sea-Dayak women weave short cotton rep petticoats and cotton sleeping wraps which are covered with beautiful and often intricate patterns. The patterns are made in the following manner: the warp is stretched on a frame, the woman takes the first fifteen to thirty strands and ties them tightly with strips of leaves at irregular intervals, according to the design, which she carries in her memory. The next fifteen to thirty strands are similarly tied, and this process is repeated until all the threads have been utilised. The warp is then removed from the frame and dipped in a reddish dye, which colours the free portions of the warp, but the tied-up portions remain undyed; thus a light pattern is left on a coloured background, when the lashing is untied. If a three-colour design is required, as is usually the case, the first lashing is retained, and various portions of the previously dyed warp are tied up; the whole is immersed in a black dye, and then both sets of lashing are untied. The pattern is thus entirely produced in the warp, the woof is self-coloured, and does not obtrude itself in the material.

There are a very large number of designs and patterns, which are remembered by the women and handed down from mother to daughter. By far the greater number of these designs are based upon animals, whereas most of the patterns carved by the men on wooden and bamboo objects are derived from plant motives. The designs embroidered by the women on jackets and loin-cloths are usually zoomorphic in character, but the treatment of the motives is quite different from the decoration of previously described fabrics.

The decorative art of the Sea-Dayaks of Sarawak differs in character from that of the Kayans, Kenyahs, and other inland tribes.

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4. *Relics of the Stone Age of Borneo.* *By* Dr. A. C. Haddon, *F.R.S.*

Until about eighteen months ago the only authentic example known in this country of a stone implement from Sarawak was the specimen collected by A. Hart Everett, which is now in the Pitt Rivers Collection at Oxford. In December, 1898, the Sarawak Museum obtained a specimen of a different type. I discovered a third type in a Sibop house on the Tinjar River in the Baram District of Sarawak; later Dr. C. Hose, the Resident of the Baram District, obtained numerous examples from various interior tribes in his district; these he has generously presented to the University of Cambridge. The occurrence of stone implements in Borneo has been previously noted.

The implements are made of various rocks, including fibrolite, impure sandstone, arkose, silicified limestone, shale, andesite, and chalcedony. The form, too, varies greatly; some are obviously axe heads, others adze blades, while certain cylindrical forms, with a more or less cup-shaped cutting end, were probably used to extract the pith from the sago palm. In the collection are several stones of irregular form; the former use of some of them is problematical, but they have recently been used as touchstones.

The natives have a high regard for these stone implements, which have in their eyes a sacred character, and it is very difficult to persuade their owners to part with them. In all cases fowls had to be sacrificed to appease the spirits. The implements are stored with other sacred objects, and most of them are believed to be teeth, or toe-nails, of Baling Go, the Thunder God.

5. *Houses and Family Life in Sarawak.* *By* A. C. Haddon, *Sc.D., F.R.S.*

The author exhibited a series of nearly fifty lantern slides taken during his recent expedition to Sarawak, which were selected to illustrate the type of house that is common among the settled inland tribes of Borneo and the every-day life of the people. No attempt was made to distinguish between the various tribes, as their mode of life is very similar in its main features. The villages are all situated on or close by the banks of rivers; most of the houses are of large size, and may contain from half-a-dozen to sixty families. Sometimes a village consists of a single house or of a string of houses placed endwise to each other.

A house is built on piles some ten to twenty feet from the ground. Along the side facing the river is a wide verandah, which stretches down the whole length of the house. Here many of the domestic industries are carried on, and all social and public business is transacted. The dwelling-rooms of each family open by a single door on to the verandah. While the common verandah affords every facility for social intercourse the privacy of the home is thoroughly respected.

In the verandah of nearly every house is at least one trophy of the skulls of enemies, which are supposed to bring good luck and plenteous harvests. Food is occasionally offered to them, and a fire has to be kept burning beneath them, otherwise the skulls would be uncomfortable and bring misfortunes to the house. Various industries were illustrated by slides, such as the husking and winnowing of rice by the women. The houses are often ornamented with carvings or paintings of a conventional character, the style of decoration varying according to the tribe.

SATURDAY, SEPTEMBER 8.

The following Papers were read:—

1. *On the Anthropology of West Yorkshire.* *By* John Beddoe, *M.D., LL.D., F.R.S.*

The author discussed the question whether any considerable British or pre-Anglian element remained in the country around Bradford. Without coming to any positive conclusion, he was disposed to consider the inhabitants of these parts as mainly Anglian in type. More British blood remained further north, in Craven. A prevalent type about Leeds seemed to him to resemble the Burgundian Belair type of His and Rütimeyer.

2. *On the Vagaries of the Kephalic Index.* *By* John Beddoe, *M.D., LL.D., F.R.S.*

The communication is based on a description of two heads, both dolichoid in pattern, but of which the one, which was most distinctly so, gave a latitudinal index (living) of 82·3, owing to retarded ossification of the posterior part of the temporo-parietal suture. But for this the author thought the index would not have exceeded 77

3. *On certain Markings on the Frontal Part of the Human Cranium, and their Significance.* *By* A. Francis Dixon.

An examination of the frontal region of the cranium shows that, in many cases, grooves or channels are present on the bone, corresponding to the branches of the supra-orbital nerves. These grooves vary very much in appearance, as they may be simple or branched, shallow or deeply cut. They are not infrequently converted in parts of their course into little tunnels. In some cases they are found on one side of the cranium only, in others they occur on both sides; their distribution is very rarely quite symmetrical. Most frequently the grooves occur beneath the outer branches of the supra-orbital nerve, but in many cases they are found beneath the inner branches. The grooves never pass from the frontal on to the parietal bone—across the coronal suture. They often extend upwards from the supra-orbital notch, or foramen, as far as the coronal suture; in other cases they begin inferiorly at a little foramen where some branch of the nerve enters the bone. The openings of these little foramina are directed upwards towards the coronal suture, just as the openings of the nutrient foramina in the long bones are directed towards the end of the bone where growth is most active and goes on longest.

The presence of these grooves indicates a want in proportion between the growth in length of the nerves and the amount of expansion of the underlying part of the cranium. The nerves might be looked upon as constricting cords which become depressed in the developing bone as the cranium expands. The constricting portions of the nerves are often limited inferiorly at a point where some little branch enters the bone, and superiorly at the coronal suture, where the deep layers of scalp are firmly bound down to the cranium. Hence the grooves for the nerves do not cross the coronal suture and often begin inferiorly at little foramina whose openings are directed upwards. The grooves appear to indicate in the skulls in which they occur an excessive development of the frontal part of the cranial wall. In races in whom the grooves are common, and strongly marked, we would expect the presence of a tendency towards increased development and capacity of the frontal part of the cranium; while, on the other hand, in races in whom the grooves do not occur, or are rare, and but feebly marked, we would expect to find much uniformity in the shape and size of the cranium, indicating that none of its various parts are tending towards an increased development. In the purer races of mankind, with marked uniformity in the size and shape of their crania, we would look for the greatest harmony between the growth in length of the overlying structures and the amount of expansion of the various parts of the cranial wall; on the other hand, in mixed races we would be more likely to find individuals exhibiting a want of such correspondence in the amount of growth of the superficial and deeper structures. In this connection it is interesting to note that the frontal grooves are almost never found in Australian and Tasmanian skulls, that they are rare among Melanesians, slightly more common among Polynesians, while among Bushmen and Negroes, especially in Zulus and Kaffirs, they are very common, and often extraordinarily well marked. Among Negroes they are present in over 50 per cent. of the skulls examined. In the skulls obtained in the dissecting room they are present in about 41 per cent. of all cases.

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4. *On the Sacral Index.* *By* Professor D. J. Cunningham, *M.D.*, *F.R.S.*

Inasmuch as the true length of the sacral portion of the vertebral column is not indicated by the shortest distance between the apex and base of the sacrum, but rather by the length of the curve formed by the sacral vertebræ, it is proposed that, in making measurements for the determination of a sacral index, 'length' should be measured by using a tape along the concavity of the sacral curve, and not by calipers, one limb of which is placed upon the base and the other on the apex of the sacrum. Breadth (measured by calipers in the ordinary manner)

multiplied by 100 and divided by length, measured in the manner indicated, gives the true sacral index.

The curvature of the sacrum may be conveniently plotted by taking a tracing from a strip of soft metal which has been previously adapted by pressure to the front of the sacrum along its middle line. The index of curvature may be expressed by the number derived by multiplying the height of this plotted curve by 100 and dividing by the number corresponding to the true length of the sacrum.

5. *On the Microcephalic Brain.* *By* Professor D. J. Cunningham, *M.D., F.R.S.*

The brain of the microcephalic idiot may exhibit features which do not merely represent a 'fixed' embryonic condition. In one specimen the arrangement of the fissures and sulci is found to approach more closely the ape than the human type, and in almost every furrow some simian character can be detected. These simian characters must not be considered mere fœtal conditions rendered permanent. The ape-like condition existing in this brain does not as a whole correspond to that of any one ape, or group of apes, but there is a complicated mixture of features some of which are characteristic of high apes, while others find a parallel in the brain of low apes. The microcephalic brain may be regarded as a partial 'atavism.' So far as its surface markings are concerned the specimen noted has reverted in part, or wholly, to an arrangement which, in all probability, existed in some early stem-form of man.

6. *Developmental Changes in the Human Skeleton from the Point of View of Anthropology.* *By* David Waterston, *M.D., F.R.C.S.E.*

A series of specimens of the long bones of the extremities at different ages of embryonic and infantile life has been collected and examined. The methods employed in the examination were those of anthropometry, namely, osteometry and osteoscopy.

By the former, the relative lengths of the bones of the limbs at different ages have been ascertained and compared one with another, and by the latter it has been found that these bones present some definite and interesting characters. Without going minutely into the rate of growth of each segment of the upper and lower limbs, the general character was shown, and the special features of the bones at different ages were demonstrated by means of lantern slides taken from photographs of the objects. An attempt has also been made to ascertain the cause of the special characters found in the bones by investigating the time of their appearance and of their replacement by adult characters.

A comparison has also been instituted between the bones of the embryo and those of the lower races of mankind and of the higher apes, both as regards their relative length and their characters.

As it has been shown that the curvature of the spine in the lumbar region is a post-natal development, and one adapted to the assumption of the erect attitude by the infant, it was shown that in a similar way the configuration of the bones of the lower extremity alters after birth, before the infant can stand erect.

MONDAY, SEPTEMBER 10.

The following Papers and Report were read:—

1. *On the Imperfection of our Knowledge of the Black Races of the Transvaal and the Orange River Colony.* *By* E. S. Hartland, *F.S.A.*

Our information on the customs, institutions, and beliefs of the native races of the Transvaal and the Orange River Colony is derived chiefly from fragmentary

notices by missionaries, and these are not to be implicitly trusted. The black peoples of South Africa are Bantus and Bushmen-Hottentots. Though there is a general similarity of custom among them all, there are also important differences, of which some examples are given. Inquiries made by the Cape Government. The difficulty experienced by Europeans, even when long resident among the natives and intimately acquainted with them, of understanding the real meaning of their institutions. The practice of *lobola* supplies a striking example of this difficulty.

An accurate study of the native customs, institutions, and beliefs is an urgent necessity both for missionaries and for purposes of government.

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2. *On a Mould showing the Finger-prints of a Roman Sculptor of probably the Third Century.* *By* Sir William Turner, *M.B., F.R.S.*

Sir Wm. Turner exhibited a plaster mould of a head, which had been modelled by a Roman sculptor in probably the third century A.D., on which the prints of the lines on the skin of the sculptor's fingers had been preserved. The mould belonged to Mr. G. Allis, of the Roman House, Lincoln, who had obtained it during the excavation of the foundations of his house a few years ago, the site of which is within the area of a large building of Roman times, several of the columns of which are preserved in the basement of his house.

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3. *Report on the Canadian Ethnographic Survey.*—See Reports, p. 468.

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4. *The Paganism of the Civilised Iroquois.*
By David Boyle, *Curator of the Museum, Toronto.*

Notwithstanding the contact of the Iroquois, or Six Nation Indians, with white people for more than three hundred years, a very considerable number of the former have retained many of their old-time beliefs, with the forms and ceremonies appertaining thereto.

Of four thousand Caniengas (Mohawks), Senecas, Cayugas, Onondagas, Oneidas, and Tuscaroras now residing on the Grand Reserve, within sixty miles of Toronto, Ontario, fully one-fourth continue to observe the ancient feasts or dances connected with the growth and ingathering of corn and fruits, and for desired changes in weather, as well as for the cure of disease.

Some modification in the ceremonies was made about a century ago by an Onondaga named Ska-ne-o-dy'-o, who announced himself as a prophet who had paid a visit to the abode of the Great Spirit. The changes introduced by him, however, have not by any means removed the pagan character of the native beliefs, although he certainly did attempt to imitate some Christian observances.

Still, the addresses of the medicine men retain most of the old-time forms, although their significance in many cases is lost, and even the meaning of numerous words is no longer known.

The leading idea in the present form of worship is that of a Great Spirit, but this has been acquired from missionary sources; and although the Indians have adopted the idea of a heaven, they do not believe in any hell.

The quoted examples of petitions addressed to Rawen Niyoh (the Creator) illustrate the lack of assimilation of the old and new forms.

One of the most characteristic ceremonies connected with Iroquois paganism is that of the sacrifice or burning of the White Dog at the new year feast during the February moon, when the spirit of the dog, accompanied by offerings of tobacco, conveys to Niyoh information respecting the condition of his 'own people' on the Grand River Reserve.

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5. *Notes on Malay Metal-work. By* WALTER ROSENHAIN, *B.A., St. John's College, Cambridge ;* 1851 *Exhibition Commissioners' Research Scholar, University of Melbourne.*

The paper dealt with some specimens of Malay metal-work submitted to the author for microscopic and other examination by Mr. W. W. Skeat. Some Malay processes actually witnessed by Mr. Skeat were described. and the bearings of the microscopic examination on the explanations of these processes are discussed.

The first question dealt with is the production of the 'damask' pattern on a Malay kris. Microphotographs were given showing that the 'damask iron' really consists of layers of loosely welded wrought iron, the only other metal used being tool steel. The body of the blade is made of steel, and a layer of laminated 'damask iron' is welded upon either side of the central layer of steel; a thin layer of steel is welded on outside the 'damask iron.' The author believes that the striated 'damask' effect is due to the opening of the loose welds in the damask iron during the forging of the blade, steel being driven between the laminæ. The outside layer of steel is entirely ground away, and when the compound surface so produced is 'etched' by the pickling process employed, the more readily corroded steel is attacked, leaving the edges of the layers of iron as a series of narrow projecting ridges.

The tools of the Malay goldsmith were next described, and the micro-structure and composition of Malay bronzes and 'white metal' were described and discussed.

The final section of the paper dealt with the Malay method of producing chains by casting.

6. *Note on the 'Kingfisher' Kriss. By* Professor HENRY LOUIS, *M.A.*

This note describes a peculiar pattern of kriss used in a limited area in the north-east of the Malay Peninsula. The Malay legend of its origin is that a party of Malays from the Bugis islands invaded this portion of the peninsula many centuries ago; one of their leaders was known as 'the Kingfisher' (presumably on account of his rapid movements). The invasion was successful, but the leader fell in one of the last engagements. After his death his followers carved their kriss handles into shapes resembling the kingfisher's head and beak. Under Chinese influence the pattern became more ornate, until it reached the present fixed type.

The writer discovered in a pawnshop in Bangkok an earlier form of this type (possibly the only one extant): this kriss seems to have been sold by a Malay from this region, many of whom are well known to have been deported by the Siamese between the years 1790 and 1820. Colonies of their descendants still exist in Siam, and have been visited by the writer. The early type of 'Kingfisher' kriss is much more like the bird's head than the modern pattern, which is, however, now the only one seen among or known to the Malays. The region in question has rarely been visited by Europeans.

7. *On some Buddhist Sites. By* W. LAW BROS.

The author exhibited a photograph of the temple erected on the spot where Buddha 'meditated.' A sample of the sacred 'Bo' tree was also shown. The delicate carvings in these temples were exhibited and explained. What was described as the 'Tope' was a characteristic development in Buddhist sacred buildings, and sometimes these were treated with elaborate ornamentation. In addition to the sites a series of views showing the rock-caverns which enter so largely into Buddhist religious life were exhibited. These rock-caves contain specimens of the earliest Buddhist sculptures known. The author also showed views of a number of Jain temples which were among the most richly elaborate in ornamentation of all Indian sanctuaries, and also views of side-chapels and cloisters belonging to these temples, in nearly all of which the cross-legged figure of the Buddha was found.

TUESDAY, SEPTEMBER 11.

The following Papers and Report were read:—

1. *On Permanent Skin-marks, Tattooing, Scarification, &c.* *By* H. Ling Roth.

The author enumerated the various purposes for which these disfigurements were made. They were connected among other things with beliefs in the future life, it being supposed that without them one could not find his way about in the next world. They also served as charms for women at childbirth. The institution was really divisible into four divisions. The Tahitian method was the one commonly seen on our sailors. The New Zealand method, which was performed by a pricker, left behind a very deep mark in the skin, and was often performed so freely as to cover the whole skin. The West African and the Tasmanian methods differed from the preceding ones, and in the case of the last of these the marks develop into large continuous scars. They were all variations of skin deformations, but rubbed in, and they leave a permanent mark The author exhibited pictures of the various specimens of; hese different methods of tattooing, and accompanied them with pictures of the different instruments employed. The wounds made were frequently reopened in order to put in colouring juices, and owing to this they were a long time in healing, and left behind them permanent scars.

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2. *Some Peculiar Features of the Animal-cults of the Natives of Sarawak, and their Bearing on the Problems of Totemism.* *By* Charles Hose, *D.Sc., Resident of the Baram District, and* W. McDougall, *M.A.*

We had observed customs that seemed to indicate the existence of a well-developed totemism, either at the present time or in recent times, among the natives of Sarawak. We have therefore collected information bearing on this subject as diligently as possible, from all the tribes with whom we have come into intimate contact.

We found a great number and variety of peculiar rites and customs observed by the people of the different tribes in their dealings with animals and plants. We confine ourselves in this short paper (1) to giving a general account of the customs of one of the inland tribes, the Kenyahs; (2) to describing the 'Nyarong,' or spirit-helper of the Sea-Dayaks, and some similar institutions among the other tribes; and (3) to pointing out the bearing of our observations on the totem problem.

The Kenyahs are a warlike agricultural people, living as isolated communities of twenty to fifty or more families, each community inhabiting a single long house built on the river-bank. Their religion is peculiar, in that they believe in a beneficent Supreme Being and a group of departmental deities, while they attribute to every agent that affects their lives a spirit that must be properly respected and, if necessary, propitiated.

Most important to them of all the animals is the common white-headed hawk. He brings messages of warning and advice from the Supreme Being to those who know how to read the signs he gives, and he is consulted before every undertaking of importance, and sacrifices of fowls and pigs are made to him. A wooden image of the hawk stands before every house. Several other birds give them omens of lesser importance, and none of these may be killed or eaten.

The domestic fowl is killed as a sacrifice to the hawk or other powers, and its blood is sprinkled on the altar-posts of the gods and on the persons taking part in various ceremonies, especially peace-making ceremonies. The domestic pig is sacrificed in much the same way. The spirit of a pig is always charged with some prayer to be carried to the Supreme Being, and the answer is read from the markings of its liver.

The crocodiles are regarded as a friendly and allied tribe, and may be killed in

retaliation only. No Kenyah will kill a dog, and the dead body of a dog is regarded with fear.

Kenyahs will not eat the flesh of deer or horned cattle, and there are many restrictions on touching or using any parts of them.

Only old or renowned warriors will wear or touch the skin of a tiger.

One house is decorated with carvings of the gibbon on every large beam, and all Kenyahs have a dread of the Maias and the long-nosed monkey.

There thus seems to be every degree of regard paid to the different beasts, from the mere uneasy feeling in the presence of the uncanny long-nosed monkey to the elaborate cult of the hawk, and the nature of the respect paid to any species seems in nearly every case to be the direct expression of the impression made on the barbarian's mind by the behaviour of the beasts.

The Spirit-Helper.—Every Sea-Dayak hopes to be guided and helped all through his life by a spirit which announces itself to him in dreams and takes up its abode in some peculiar natural object or in some animal. In the latter case the Dayak will never kill or eat one of the same species of animal, and will lay the same prohibition on all his descendants, so that a whole family may come to pay especial regard to one species of animal for many generations. A similar institution occurs, though less commonly, among the other tribes. In such cases we seem to be able to trace sometimes the actual origin and growth of a totem.

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3. *Report on the Ethnography of the Malay Peninsula.*

See Reports, p. 393.

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4. *On the Present State of our Knowledge of the Modern Population of Egypt. By* D. RANDALL MACIVER, *M.A.*

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5. *Perforate Humeri in Ancient Egyptian Skeletons. By* Professor A. MACALISTER, *F.R.S.*

In sorting out our Cambridge collection of Egyptian bones I have noted the frequency of supra-articular perforation of the humerus, especially in the bones from Libyan graves. I did not begin to count the number of examples until more than three-fourths of the series had been put away in store-cases, but out of the last twenty boxes opened I found that out of 682 humeri 390 were perforate and 292 imperforate. The percentage of perforation is therefore 57·2.

This exceeds anything hitherto published. Of ancient North Americans the percentage of perforate bones out of 300 specimens is 40 per cent. In one collection from the Gila Valley, in Arizona, 48 perforate bones were found out of 89, a percentage of 53·9; but this is exceptionally high, and the number of bones is not large. In our Cambridge collection when I began to count I found out of the first 115 bones that 65 were perforated; so, had I none but this series, the percentage would have come out 56·5.

The Libyans may therefore, I think, claim to hold the record. In our dissecting-room there were three instances out of the last hundred bodies examined. Other statistics will be found in Messrs. Matthews and Lamb's article on the subject.[1]

The authors just quoted are most probably correct in considering this as an acquired character. The youngest specimen obtained was in a humerus of a child probably six years old. I have not seen any genuine approach to this condition among 100 fœtal humeri examined for the purpose. As far as I know, it has never been found in a fœtal bone.

It is a perforation of the shaft well above the epiphysial junction line. The

[1] *Mem. Amer. National Acad. Sci.*, vi, 217.

distal extremity of the diaphysis thickens below the hole down to the place where the epiphysis is set upon it.

It is always in the intra-articular part of the olecranon fossa, below the line of reflexion of the synovial membrane that crosses the middle of the fossa. It is therefore quite distinct from the vascular holes with which Topinard associates it, as these are always extra-articular [the vessels are chiefly derived from the inferior profunda].

Of these perforate humeri 172 were right and 218 were left. As far as could be determined from size, shape, and from the accompanying pelvic bones, 192 were male and 198 were female. There is thus the same preponderance of left and female over right and male bones which was noticed by the describers of the Hemenway Collection, leading one to speculate as to the nature of the work which predisposed to the perforation—the mill, the shadoof, or the mattock.

As to the sizes of the holes, they were mostly oval or elliptical, with the long axis transverse or nearly so, and the distribution of their sizes is shown in the accompanying table:—

Length of Long Axis in mm.	Male.		Female.	
	Right.	Left.	Right.	Left.
1–4	17	9	12	10
5–9	54	58	52	63
10–12	14	37	22	39
Over 12	1	2	0	0
Total . .	86	106	86	112

In the few recent examples, which were large, the hole was actually open in the recent state; when small it is usually closed by membrane; 27 were young bones with un-united upper epiphysis, 5 coexisted with the supracondylar process. The opening is reniform or bilobed in 33.

This note is only preliminary, as the subject is sufficiently important to require still further study. I have, however, been able to determine that while in ordinary extension and flexion the tips of the processes do not press on the humerus, yet by forced extension and forced flexion contact can be made to take place, especially when the elbow is forcibly extended, with the hand in the position of pronation.

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6. *On Anthropological Observations made by Mr. F. Laidlaw in the Malay Peninsula (Skeat Expedition). By* W. L. H. Duckworth.

The anthropological results of the Skeat Expedition comprise museum specimens in the form of a skeleton of a native of the Pangan tribe (Kedah), of samples of native hair, and also a collection of measurements by Mr. Laidlaw.

The skeleton is that of an adult male, whose stature was distinctly small (about 5 feet). The skull presents a combination of features commonly found in the skulls of negroes with those which characterise the crania of infants, the whole constituting evidence of the lowly physical type of the individual. The bones of the skeleton show signs of widespread disease, possibly of a congenital nature. Mr. Laidlaw's measurements and observations relate to members of the same tribe, and are to be welcomed as affording precise information about a race of Malayan aborigines hitherto little investigated. Perhaps the most interesting point to notice is the small average stature of the Pangans (about 5 feet for adult men). Though dwarfish, they are, however, markedly taller than the African dwarfs. It is also noteworthy that differences in the colour of the skin (varying shades of dark brown) and in the character of the hair occur in the different tribes. It is important to notice that they present comparatively few anatomical features which can be claimed as evidence of an approximation to the ape. How-

ever primitive in their mode of life, they are anatomically truly terrestrial and human. The present communication is only a preliminary account of Mr. Laidlaw's results; moreover, there is much information available through the efforts of the Skeat Expedition regarding the mode of life, language, customs, and religious belief of these fast-disappearing aborigines. The Association is therefore to be congratulated on having, by contributing to the Skeat Expedition, assisted materially in rescuing these records of the Pangan tribe of the Malay Peninsula.

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7. *On Crania collected by Mr. J. Stanley Gardiner in his Expedition to Rotuma. By* W. L. H. Duckworth.

The subject of this communication is a collection of nine crania from the above-mentioned locality. The results of a craniological investigation show that while considerable individual differences exist, there are at least two types of skull to be met with in the island of Rotuma. These are in the first place a variety of the form of cranium usually found among Polynesian natives, though possessing certain characteristics which may almost be described as Mongolian; and in the second place the type of cranium characteristic of Melanesians occurs in Mr. Gardiner's collection. That such different types should be met with in one small island is in accordance with what would be expected on *à priori* grounds when it is considered that Rotuma is situated at the centre of contact of three important ethnical areas, viz., the Polynesian to the east, the Melanesian to the south-west, and the Micronesian (where Mongolian elements are discernible among the natives) to the north-west.

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8. *A System of Classification of Finger Impressions. By* J. G. Garson, *M.D., Expert Adviser and Instructor on Identification, Home Office.*

This system of classification of finger impressions has been devised to be worked in conjunction with classification of records by measurements of the head and limbs for the purpose of facilitating search for previous records of criminals. It is also applicable for the classification of small collections of records without the concurrent use of measurements.

The objects aimed at in preparing this classification have been to get a moderate number of divisions under which the various patterns and combinations of patterns occurring in the arrangement of the ridges of the skin on the palmar surface of the terminal phalanges of the digits of the hand may be classified, so that each division shall contain approximately an equal percentage of the total number of records dealt with, using for the purpose the fewest number of digits that will suffice to get such a distribution, and including only the impressions of those digits which are taken in all countries where the Bertillon system of identification has been adopted—namely, the first four digits of the right hand. The patterns which the ridges form are four in number, and are graphically indicated by the use of the following signs:—

An arch thus	/\
A loop which opens on the left	/
A loop opening to the right	\
A whorl of any kind	O

The representations of the ridge-patterns depicted by these signs from the impressions of the several digits in order of succession constitute the finger formula of an individual, which should be noted on a prominent part of each record so as to be readily seen.

It has been found that the patterns and their combinations on the thumb and three following fingers may be conveniently arranged in ten divisions. The thumb and forefinger are always required in the classification, but when the divisions given by these digits are large, the middle finger or the middle and ring finger

impressions are also needed to equalise the size of each division to as nearly as possible 10 per cent. of the total number of records.

In the first instance the records are classified into two divisions by the ridge-pattern on the thumb, according as this happens to be A, an arch or either form of loop; B, a whorl.

Each of these two groups is broken up into four smaller divisions by the pattern on the forefinger according as it is (*a*) an arch; (*b*) a loop with the mouth opening to the left; (*c*) a loop with the opening to the right; (*d*) a whorl.

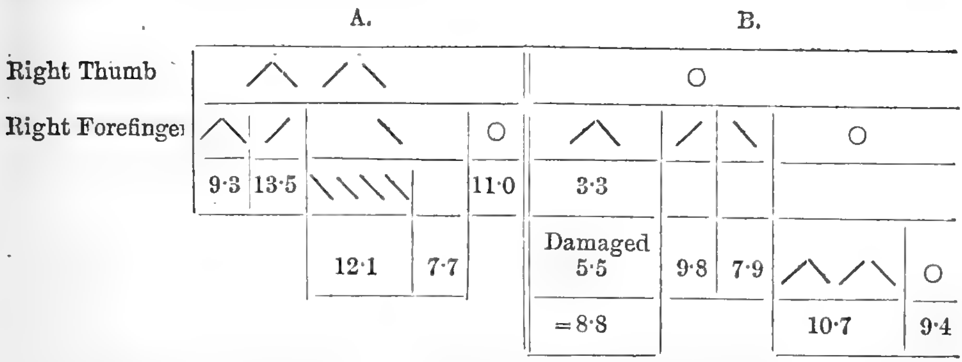
Of the eight divisions thus obtained no further subdivision is necessary of six groups—namely, of *a*, *b*, and *d* of the A division, and of *a*, *b*, and *c* of the B division.

In the A division, further subdivision of the *c* group by the middle and ring fingers is necessary. This is done by separating the cases where there are loops on each of the four digits from those in which there is any other combination of patterns on the thumb, mid, and ring fingers. Thus we obtain five groups in this first division.

Again, in the B division—namely, the cases in which there is a whorl on the thumb—subdivision has to be resorted to in the *d* group when there is a whorl on the forefinger as well as on the thumb. This is done by separating the cases where the middle finger bears a whorl from those in which there is an arch or either form of loop. Thus we obtain five groups in this second division.

We have now got ten groups, which are of approximately equal size, except the *a* group of the B division—that in which the thumb bears a whorl and the forefinger an arch, which is considerably smaller than the others, but this cannot be obviated. In any given number of individuals there will always be some in whom one or more of the four fingers used in classification have been damaged from some cause or other, so that the pattern of the ridges is undecipherable, or one or more fingers of either hand have been lost partially or completely; especially is this the case amongst the labouring classes in manufacturing districts or towns. In adult criminals such cases amount to about 5·5 per cent. In any system of classification it is necessary to provide for such cases either by making a separate group of them or by placing them with some other group as may be found more convenient. If the latter course be adopted, and they are added to *a* of the B group, it will be brought up to the level of several of the other groups.

The following is the scheme of classification reduced to tabular form, and the approximate percentage of the records in each of the ten divisions is indicated by the figures given in the lowest line:—



With the above ten divisions of the finger impressions worked in conjunction with and secondary to classification by measurements, sufficient power is available to enable the records of a large number of criminals to be easily manipulated. For example, if only four measurements be used in the tripartite classification, which is universally followed, we have 81 divisions; by the employment of this decimal division by finger-prints, a total of 810 divisions are obtained; while if five measurements be taken, as adopted in England, which gives 243 divisions, by the

combined system, we increase the power of effective classification tenfold, and obtain no less than 2,430 divisions, and that without straining either source of classification.

WEDNESDAY, SEPTEMBER 12.

The following Papers and Report were read:—

1. *The Sense of Effort and the Perception of Force.* *By* Professor G. J. STOKES, *M.A.*

According to the most generally accepted view the idea of force is obtained from the muscular sense. It has also been attributed to touch. The most important question is whether the perception is connected with the motor or sensory nerves. If the latter view be adopted, it has been thought that this sensation can reveal nothing of the nature of the objective cause. As recent investigation seems to compel the adoption of the latter view, the objective character of the perception can only be saved if we admit the presence of an objective character in all sensation. If Wundt's theory of the original functional indifference of the nerves be accepted, we may yet be enabled to remove the difficulties in the way of admitting such an objective character. The true difference between the perception of force and other sensations will then lie, not in the process by which the phenomenon is apprehended, but in the nature of the phenomenon apprehended. We may thus have an apprehension of an objective external reality—the same reality which underlies the phenomena of dynamics. The principle of Least Action may perhaps explain the directive character of vital and voluntary processes.

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2. *On Interpolation in Memory.*[1] *By* Professor MARCUS HARTOG, *M.A., D.Sc.*

Many educational syllabuses that profess to rest on a psychological base assume that the only guidance for action is a sensation which has been memorised by frequent repetition. The mind, however, seems to have the power of classifying the memories of each category apart and in order of magnitude and direction, completing the records of single memories with what may be compared with an interpolation-curve, and even extrapolating on either side; so that, if a suitable response have been learned to a limited number of sensations, a new sensation of the same category will produce a new appropriate response. This capacity for interpolating has been long recognised in various arts, and is known as 'faculty,' 'feeling,' &c. It has not, however, been definitely recognised by the psychologist, who has asked whether the *conscious* memory and judgment can construct intermediate sensations between those he has learned from experience, rather than whether there is a power in virtue of which it can recognise the appropriate position of new sensations, or appropriately act on the stimulus of new sensations when they occur.

Similarly with combinations of intermediate sensations, the mind can simultaneously act on them and execute the combined appropriate response in much the same way as the pencil of a tide-predicting machine is simultaneously acted upon by the independent wheels. This is shown by the now received fact (finally proved by Richet) that each mental act takes about the tenth of a second, and any act of conscious (*sit venia verbo*) combination and judgment is usually out of the question from a lack of adequate time.

Illustrations of these views were quoted from the domains of housekeeping, the plastic arts, cards, billiards, and language. It was urged that *à priori* methods of instruction based on incomplete premises must be regarded with extreme caution.

[1] Published in the *Contemporary Review* for October 1900.

3. *The Defensive Earthworks of Yorkshire.* *By* Mrs. Armitage.

The author describes the various types of earthworks in Yorkshire—Roman camps, hill forts, and boundary earthworks—and gives a summary of the results of recent researches regarding these three classes of earthworks.

A fourth class very frequent in Yorkshire is the moated hillock, with moated court attached. It has been assigned in turn to the Britons, Romans, Saxons, and Danes. The author gives reasons why none of these views is probable, and shows the erroneousness of the theory of Mr. G. T. Clark, now so widely accepted, that the Anglo-Saxon *burh* was a hillock of this kind, its meaning in Anglo-Saxon literature being clearly a *fortified town*. The author produces the following arguments for the Norman origin of these hillocks (called by the Normans *mottes*): (*a*) the Normans are known to have built such earthworks in Normandy and Ireland, and are represented in the Bayeux tapestry as throwing up a similar work at Hastings; (*β*) the type belongs to the age of feudalism, and answers to the needs of the Normans in the United Kingdom; (*γ*) the Norman castles mentioned by the contemporary chroniclers or by Domesday Book as constructed by the Conqueror or his followers have nearly all of them *mottes*.

The evolution of the Castle, the personal fortification of the feudal chieftain, accompanied the evolution of society from the tribal to the feudal type.

4. *On the Prehistoric Antiquities of Rumbald's Moor.* *By* Butler Wood.

5. *On the Occurrence of Flint Implements of Palæolithic Type on an old Land-surface in Oxfordshire, near Wolvercote and Pear Tree Hill, together with a few Implements of various Plateau Types.* *By* A. M. Bell, *M.A.*

At Wolvercote, near Oxford, there is a large section of a quaternary river-gravel which has produced the usual fauna, Elephas primigenius &c., and many fine implements of human workmanship. This gravel cuts into and is consequently newer than a previous land-surface. A portion of this surface is found at Wolvercote and another portion at Pear Tree Hill, about half a mile distant. In both places flint implements of palæolithic type, together with bulbed flakes and a few implements of plateau type, have been found. In every case the flints are ochreous, which distinguishes them from those which belong to the river-gravel at Wolvercote.

The older surface has been previously described as Northern Drift. It is supposed by the author to be a *remaniement* of the true Northern Drift, but to have been deposited under semi-frozen conditions. It must be anterior to the river-valley, and consequently its relics of man are the oldest as yet obtained from the Thames Valley.

The drift in question most resembles the drifts of Caddington, described by Mr. G. Worthington Smith, and some sections of the Lower Greensand near Limpsfield. Both of these drifts are implementiferous, and the author would correlate the Wolvercote and Pear Tree Hill surface with these drifts.

6. *On the Physical Characteristics of the Population of Aberdeenshire.* *By* J. Gray, *B.Sc., and* J. F. Tocher, *F.I.C.*

These observations were taken at the Lonach gathering in Strathdon, a district lying right at the head of the valley of the Don. The district is comparatively isolated, the nearest railway station being over twelve miles distant.

Our principal object was to ascertain what difference if any existed between the people in the upper ends of the river valleys and the people on the eastern sea-

board, the anthropological statistics of which have been recently ascertained. The following results show that a very considerable difference exists; and it being highly probable that a more primitive stratum of the population is always to be found in the upper ends of river valleys, the results are of great interest from this point of view.

The pigmentation and nose statistics of the whole of the people attending the gathering, namely, 361 males and 243 females, were taken at the gate by two observers. Later on the same statistics, with the addition of measurements of the head and of stature, were taken in a tent in the grounds, about ninety adult males, natives of the district, being measured. The people observed at the gate contained a small percentage of visitors from a distance, which may account for the difference in the results obtained at the gate and in the tent.

	Hair				Eyes			Types of Noses					
	Fair	Red	Brown	Dark	Light[1]	Med	Dark	Straight	Roman	Wavy	Concave	Jew
Males:												
W. Aberdeenshire (gate)	10	8	42	40	37	48	14	79	15	3	2	1
W. Aberdeenshire (tent)	5	8	40	47	38	45	17	56	22	13	6	3
E. Aberdeenshire (gate)	9	6	66	19	26	51	23	56	17	7	17	3
E. Aberdeenshire (tent)	18	2	40	40	35	46	19	66	20	8	4	1
Females:												
W. Aberdeenshire (gate)	8	6	36	50	39	34	27	82	9	2	6	1
E. Aberdeenshire (gate)	10	6	55	29	22	39	39	60	7	5	27	1

An examination of the above table shows that on the average the hair is much darker in West than in East Aberdeenshire; a result which might be accounted for by the presence of a larger percentage of the North German blonde type on the east coast. The eyes, however, are lighter in the west than in the east; an anomalous result which is not so easily explained.

The following table gives an analysis of the measurements of the ninety adult males taken in the tent and their correlations, with pigmentation and types of noses, corresponding results obtained from the rural population of E. Aberdeenshire (Mintlaw gathering) being given for the sake of comparison.

	Per cent. of Population	Heads		Stature	Nigrescence		Types of Noses				
		Bdth.	Lgth.	Ft. In.	Hair	Eyes	S.	R.	W.	C.	J.
W. Aberdeenshire (90 persons)—											
General Averages	—	157	198	5 8¾	76	40	56	22	13	6	3
Group I. (158-167)	50	161	200	5 9¼	78	38	55	18	20	0	7
„ II. (153-157)	35	155	196	5 8¼	79	42	53	34	3	10	0
„ III. (149-152)	12	151	197	5 9	67	45	64	18	18	0	0
„ IV. (145-148)	2	146	199	5 9¼	83	50	100	—	—	—	—
E. Aberdeenshire (169 persons)—											
General Averages	—	153	195	5 8¼	68	41	66	20	8	4	1
Group I. (158-167)	14	161	199	5 9	70	39	70	21	9	0	0
„ II. (153-157)	44	155	195	5 8¼	66	40	68	20	11	0	1
„ III. (149-152)	28	150	193	5 7¾	67	45	61	22	4	6	0
„ IV. (142-148)	14	146	192	5 7½	69	37	71	17	4	4	4

[1] *Blue* eyes were taken separately at the Lonach gathering, and were found to form about 10 per cent. of the *light* eyes, which in the table includes blue eyes

In the head-breadth frequency curve of the population of E. Aberdeenshire we found two well-marked peaks at 150 mm. and 155 mm., and two lesser peaks at 145 mm. and 160 mm. Taking these breadths as centres, we have divided the people into four groups, the limiting breadths being marked opposite each group in the above table.

The general averages given in the table show that in W. Aberdeenshire the people have broader and longer heads: they are taller by $\frac{3}{4}$ inch, they are darker in hair and lighter in eyes, and they have rather higher percentages of Roman, wavy, and concave noses than in E. Aberdeenshire.

The first column in the table shows approximately the percentage which each group forms of the population. Group I. is much better represented in the west than in the east, being 50 per cent. of the population in the former case and only 14 per cent. in the latter case. The average breadths and lengths of the head in this group come out almost exactly the same in the west and in the east, and the stature (5 feet $9\frac{1}{4}$ inches), which is very high for an average, differs only by $\frac{1}{4}$ inch in the two places. The nigrescence, which is calculated by a formula in which the relative value and percentage of all the colours are taken into account,[1] shows that in both the east and the west this group is darker in hair and lighter in eyes than the general average of the population. It is evidently the presence of a larger percentage of this group in the west which accounts for its superiority in physique over the east. Group II. is well represented in both east and west. Groups III. and IV. are, however, almost completely absent in the west, the total numbers, eleven and two, in these groups in the west being so small as to make the averages for stature, &c., given in the table unreliable.

It seems reasonable to conclude from these results that, in Aberdeenshire, at some distant date, an early, tall, broad-headed, light-eyed people have been driven inland by later immigrants, who were shorter, had narrower heads, and were of the blonde type.

A frequency curve of breadths of round barrow heads shows that Groups I. and II. were well represented in the Bronze age in the British Isles. Groups III. and IV. have the breadths of long barrow heads, which, however, are much longer (208 mm. on the average). The Rowgrave heads of N. Germany, whose average length is given as about 200 mm., come much nearer to Group III.; and as these probably represent the aboriginal blonde race of N. Germany, it is reasonable to assume that our Group III. represents blonde immigrants from N. Germany, who when they arrived in Aberdeenshire found the country in possession of a tall, broad-headed, dark-haired, blue-eyed people, the descendants of the men of the Bronze age. The resemblance of Group I. to Deniker's Adriatic type is significant when taken in conjunction with the fact that bronze first came into the British Isles from S.E. Europe.

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7. *Report on the Age of Stone Circles.*—See Reports, p. 461.

[1] See *Journ. Anthropological Institute*, 1900.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION—Professor SYDNEY H. VINES, M.A., D.Sc., F.R.S.

THURSDAY, SEPTEMBER 6.

In the absence of the President the following Address was read by Dr. D. H. SCOTT, F.R.S.:—

THERE has been considerable difference of opinion as to whether the present year marks the close of the nineteenth or the beginning of the twentieth century. But whatever may be the right or the wrong of this vexed question, the fact that the year-date now begins with 19, instead of with 18, suggests the appropriateness of devoting an occasion such as the present to a review of the century which has closed, as some will have it, or, in the opinion of others, is about to close. I therefore propose to address you upon the progress of Botany during the nineteenth century.

I am fully conscious of the magnitude of the task which I am undertaking, more especially in its relation to the limits of time and space at my disposal. So eventful has the period been that to give in any detail an account of what has been accomplished during the last hundred years would mean to write the larger half of the entire history of Botany. This being so, it might appear almost hopeless to attempt to deal with so large a subject in a Presidential Address. But I trust that the very restrictions under which I labour may prove to be rather advantageous than otherwise, inasmuch as they compel me to confine attention to what is of primary importance, and thus to give special prominence to the main lines along which the development of the science has proceeded.

Statistics.

We may well begin with what is, after all, the most fundamental matter, viz., the relative numbers of known species of plants at the beginning and at the end of the century. It might appear that the statistics of plants was a subject susceptible of very simple treatment, but unfortunately this is not the case. It must be remembered that a 'species' is not an invariable standard unit, like a pound or a pint, but that it is an idea dependent upon the subjectivity of individual botanists. For instance, one botanist may regard a certain number of similar plants as all belonging to a single species, whilst another may find the differences among them such as to warrant the distinction of as many species as there are plants. It is this inevitable variation in the estimation of specific characters which renders it difficult to deal satisfactorily with plants from the statistical point of view. However, the following figures may be regarded as giving a fair idea of the increase in the number of 'good' species of living plants.

It is generally stated that about 10,000 species of plants were known to Linnæus in the latter half of the eighteenth century, of which about one-tenth were Cryptogams; but so rapid was the progress in the study of new plants at that time that the first enumeration of plants published in the nineteenth century,

the 'Synopsis' of Persoon (1807), included as many as 20,000 species of Phanerogams alone. Turning now to the end of the century, we arrive at the following census, for which I am indebted mainly to Professor Saccardo (1892) and to Professor de Toni who has kindly given me special information as to the Algæ:—

Species of Phanerogams indicated in Bentham and Hooker's 'Genera Plantarum' (Durand, 'Index,' 1888).

Dicotyledons	78,200
Monocotyledons	19,600
Gymnosperms	2,420
	100,220
Estimated subsequent additions (Saccardo)	5,011
Total Phanerogams	105,231

Species of Pteridophyta (indicated in Hooker and Baker's 'Synopsis;' Baker's 'New Ferns' and 'Fern Allies').

Filicinæ (including Isoëtes), about	3,000
Lycopodinæ, about	432
Equisetinæ, about	20
Total Pteridophyta	3,452

Species of Bryophyta (Saccardo's Estimate).

Musci	4,609
Hepaticæ	3,041
Total Bryophyta	7,650

Species of Thallophyta.

Fungi (including Bacteria) (Saccardo)	39,663
Lichens (Saccardo)	5,600
Algæ (incl. 6,000 Diatoms) (de Toni)	14,000
Total Thallophyta	59,263

Adding these totals together—

Phanerogams	105,231
Pteridophyta	3,452
Bryophyta	7,650
Thallophyta	59,263
we have a grand total of	175,596

as the approximate number of recognised species of living plants.

These figures are sufficiently accurate to show how vast have been the additions to the knowledge of plants in the period under consideration, and they afford much food for thought. In the first place, they indicate how closely connected has been the growth of this branch of Botany with the exploration and opening up of new countries which has been so characteristic a feature of the century. Again, no one can consider these figures without being struck by the disparity in the numbers of species included in the different groups; a most interesting topic, which cannot, however, be entered upon here. It must suffice to point out in a general way that the smaller groups represent families of plants which attained their numerical zenith in long past geological periods, and are now decadent, whilst the existing flora of the world is characterised by the preponderating Angiosperms and Fungi.

We may venture to cast a forward glance upon the possible future development of the knowledge of species. Various partial estimates have been made as to the probable number of existing species of this or that group, but the only comprehensive estimate with which I am acquainted is that of Professor Saccardo (1892). He begins with a somewhat startling calculation to the effect that there are at least 250,000 existing species of Fungi alone, and he goes on to suggest that probably the number of species belonging to the various other groups would amount to 150,000; hence the total number of species now living is to be estimated at over 400,000. On the basis of this estimate it appears that we have not yet made the acquaintance of half the contemporary species; so that there remains plenty of occupation for systematic and descriptive botanists, especially in the department of Fungology. It is also rather alarming, in view of the predatory instincts of so many of the Fungi, to learn that they constitute so decided a majority of the whole vegetable kingdom.

In spite of the great increase in the number of known species, it cannot be said that any essentially new type of plant has been discovered during the century. So far as the bounds of the vegetable kingdom have been extended at all, it has been by the annexation of groups hitherto regarded as within the sphere of influence of the zoologists. The most notable instance of this has occurred in the case of the Bacteria, or Schizomycetes, as Naegeli termed them. These organisms, discovered by Leeuwenhoek 200 years ago, had always been regarded as infusorian animals until, in 1853, Cohn recognised their vegetable nature and their affinity with the Fungi. These plants have acquired special importance, partly on account of the controversy which arose as to their supposed spontaneous generation, but more especially on account of their remarkable zymogenic and pathogenic properties, so that Bacteriology has become one of the new sciences of the century.

Classification.

Having gained some idea of the number of species which have been recognised and described during the century, the next point for consideration is the progress made in the attempt to reduce this mass of material to such order that it can be intelligently apprehended; in a word, to convert a mass of facts into a science; 'Filum ariadneum Botanices est systema, sine quo chaos est Res Herbaria' (Linnæus).

The classification of plants is a problem which has engaged attention from the very earliest times. Without attempting to enter into the history of the matter, I may just point out that, speaking generally, all the earlier systems of classification were more or less artificial, the subdivisions being based upon the distinctive features of one set of members of the plant. When I say that of all these systems that proposed by Linnæus (1735) was the most purely artificial, I do not imply any reproach: if it was the most artificial, it was at the same time the most serviceable, and its author was fully aware of its artificiality. This system is generally regarded as his most remarkable achievement; but the really great service which Linnæus rendered to science was the clear distinction which he for the first time drew between systems which are artificial and those which are natural. Recognising, as he did, his inability to frame at that period a satisfactory natural system, he also realised that with the increasing number of known plants some more ready means of determining them was an absolute necessity, and it was for this purpose that he devised his artificial system, not as an end, but as a means. The end to be kept in view was the natural classification: 'Methodus naturalis est ultimus finis Botanices' is his clearly expressed position in the 'Philosophia Botanica.'

There is a certain irony in the fact that the enthusiastic acceptance accorded to his artificial system throughout the greater part of Europe contributed to postpone the realisation of Linnæus's cherished hopes with regard to the attainment of a natural classification. It was just in those countries, such as Germany and England, where the Linnean system was most readily adopted that the development of the natural system proceeded most slowly. It was in France, where the Linnean system never secured a firm hold, that the quest of the natural system was

pursued; and it is to French botanists more particularly that our present classification is due. It may be traced from its first beginnings with Magnol in 1689, through the bolder attempts of Adanson and of Bernard de Jussieu (1759), to the relatively complete method propounded by Antoine Laurent de Jussieu in his 'Genera Plantarum,' just 100 years later.

The nineteenth century opened with the struggle for predominance between the Jussiean and the Linnean systems. In England the former soon obtained considerable support, notably that of Robert Brown, whose 'Prodromus Floræ Novæ Hollandiæ,' published in 1810, seems to have been the first English botanical work in which the natural system was adopted; but it did not come into general use until it had been popularised by Lindley in the thirties.

Meantime the Jussiean system had been extended and improved by Auguste Pyrame de Candolle (1813–24). It is essentially the Candollean classification which is now most generally in use, and it has been immortalised by its adoption in Bentham and Hooker's 'Genera Plantarum,' one of the great botanical monuments of the century. In Germany, however, it has been widely departed from, the system there in vogue being based upon Brongniart's modification (1828, 1850) of de Candolle's method as elaborated successively by Alex. Braun (1864), Eichler (1876–83), and Professor Engler (1886, 1898). It must be admitted that for the last fifty years the further evolution of the natural system, at any rate so far as Phanerogams are concerned, has been confined to Germany.

One of the more important advances in the classification of Phanerogams was based upon Robert Brown's discovery in 1827 of the gymnospermous nature of the ovule in Conifers and Cycads, which led Brongniart (1828) to distinguish these plants as 'Phanérogames gymnospermes;' and although the systematic position of these plants has since then been the subject of much discussion, the recognition of the Gymnospermæ as a distinct group of archaic Phanerogams is now definitely accepted.

Moreover, the greatly increased knowledge of the Cryptogams has involved a considerable reconstruction in the classification of that great sub-kingdom. One of the most striking discoveries is that first definitely announced by Schwendener (1869) concerning Lichens, to the effect that the body of a Lichen consists of two distinct organisms, an Alga and a Fungus, living in symbiosis; a discovery which was so nearly made by other contemporary botanists, such as de Bary, Berkeley, and Sachs, and which can be traced back to Haller and Gleditsch in the eighteenth century.

But the discoveries which most affected the classification of the Cryptogams are those relating to their reproduction. Whilst it had been recognised, almost from time immemorial, that Phanerogams reproduce sexually, sexuality was denied to Cryptogams until the observations on Liverworts and Mosses by Schmidel and by Hedwig (of whom it was said that he was born to banish Cryptogamy) in the eighteenth century; and even as late as 1828 we find Brongniart classifying the Fungi and Algæ together as 'Agames.' But in the middle third of the nineteenth century, by the labours of such men as Thuret, Pringsheim, Cohn, Hofmeister, Naegeli, and de Bary, the sexuality of all classes of Cryptogams was clearly established. It is worthy of note that, although the sexuality of the Phanerogams had been accepted for centuries, yet the details of sexual reproduction were first investigated in Cryptogams. For it was not until 1823 that Amici discovered the pollen-tube, and it was more than twenty years later (1846) before he completed his discovery by ascertaining the true significance of the pollen-tube in relation to the development of the embryo; whilst it remained for Strasburger to observe, thirty years later, the actual process of fertilisation.

The discovery of the reproductive processes in Cryptogams not only facilitated a natural classification of them, but had the further very important effect of throwing light upon their relation to Phanerogams. Perhaps the most striking botanical achievement of the nineteenth century has been the demonstration by Hofmeister's unrivalled researches (1851) that Phanerogams and Cryptogams are not separated, as was formerly held, by an impassable gulf, but that the higher Cryptogams and the lower Phanerogams are connected by many common features.

The development of the natural classification, of which an account has now been given, proceeded for the most part on the assumption of the immutability of species. As Linnæus expressed it in his 'Fundamenta Botanica,' 'species tot numeramus, quot diversæ formæ in principio sunt creatæ.' It is difficult to understand how, with the point of view, the idea of affinity between species could have arisen at all; and yet the establishment of genera and the attempts at a natural system prove that the idea was operative. The nature of the prevalent conception of affinity is well conveyed by Linnæus's aphorism, 'Affines conveniunt habitu, nascendi modo, proprietatibus, viribus, usu.'

But a conviction had been gradually growing that the assumed fixity of species was not well founded, and that, on the contrary, species are descended from pre-existent species. This view found clear expression in Lamarck's 'Philosophie Zoologique,' published early in the century (1809), but it did not strongly affect public opinion until after the publication of Darwin's 'Origin of Species' in 1859. Regarded from this point of view the problems of classification have assumed an altogether different aspect. Affinity no longer means mere similarity, but blood-relationship depending upon common descent. We no longer seek a 'system' of classification; we endeavour to determine the mutual relations of plants. The effect of this change has been to stimulate the investigation of plants in all their parts and in all stages of their life, so as to attain that complete knowledge of them without which their affinities cannot be accurately estimated. If the classification of Cryptogams is, at the present moment, in a more satisfactory position than that of Phanerogams, it is just because the study of the former group has been, for various reasons, more thorough and more minute than that of the latter.

Palæophytology.

The stimulating influence of the new doctrine was not, however, confined to the investigation of existing plants; it also gave a remarkable impulse to the study of fossil plants, inasmuch as the theory of descent involves the quest of the ancestors of the forms that we now have around us. Marvellous progress has been made in this direction during the nineteenth century, by the labours more especially of Brongniart, Goeppert, Unger, Schimper, Schenck, Saporta, Solms-Laubach, Renault, on the Continent, and in our own country of Lindley and Hutton, Hooker, Carruthers, and more especially of Williamson. So far-reaching are the results obtained that I can only attempt the barest summary of them. I may perhaps best begin by saying that only a small proportion of existing species have been found in the fossil state. In illustration I may adduce the statement made by Mr. Clement Reid in his recent work, 'The Origin of the British Flora,' that only 270 species, that is, about one-sixth of the total number of British vascular plants, are known as fossils. Making all due allowances for the imperfection of the geological record, for the limited area investigated, and for the difficulty of determination of fragmentary specimens, it may be stated generally that the number of existing species has been found to rapidly diminish in the floras of successively older strata; none, in fact, have been certainly found to persist beyond the Tertiary period. Certain existing genera, belonging to the Gymnosperms and to the Pteridophyta, have, however, been traced far down into the Mesozoic period. Similarly, the distribution in time of existing natural orders does not coincide with that of existing genera; thus the Ferns of the Carboniferous epoch apparently belong, for the most part, if not altogether, to the order Marattiaceæ, but they are not referable to any of the existing genera.

Moreover, altogether new families of fossil plants have been discovered: such are, among Gymnosperms, the Cordaitaceæ and the Bennettitaceæ; among Pteridophyta, the Calamariaceæ, the Lepidodendraceæ, the Sphenophyllaceæ, and the Cycadofilices. It is of interest to note that all these newly discovered families can be included within the main subdivisions of the existing flora; in fact, no fossil plants have been found which suggest the existence in the past of groups outside the limits of our Phanerogamia, Pteridophyta, Bryophyta, and Thallophyta.

It cannot be said that the study of Palæobotany has as yet made clear the

ancestry and the descent of our existing flora. To begin with the angiospermous flowering plants, it has been ascertained that they make their first appearance in the Cretaceous epoch, but we have no clue as to their origin. The relatively late appearance of Angiosperms in geological time suggests that they must have sprung from an older group, such as the Gymnosperms or the Pteridophyta; but there is no evidence to definitely establish either of these possible origins. Then as to the origin of the Gymnosperms, whilst it cannot be doubted that they were derived from the Pteridophyta, the existing data are insufficient to enable us to trace their pedigree. The most ancient family of Gymnosperms, the Cordaitaceæ, can be traced as far back as any known Pteridophyta, and cannot, therefore, have been derived from them; but the fact that the Cordaitaceæ exhibit certain cycadean affinities, and the discovery of the Cycadofilices, suggest that what may be termed the cycadean phylum of Gymnosperms (including the Cordaitaceæ, Bennettitaceæ, Cycadaceæ, and perhaps the Ginkgoaceæ) had its origin in a filicineous ancestry, of which, it must be admitted, no forms have as yet been recognised.

Turning to the Pteridophyta, the origin of the Ferns is still quite unknown: the one fact which seems to be clear is that the eusporangiate forms (Marattiaceæ) are more primitive than the leptosporangiate. With regard to the Equisetinæ, the Calamariaceæ were no doubt the ancestors of the existing and of the fossil Equisetums. Similarly, in the Lycopodinæ, the palæozoic Lepidodendraceæ were the forerunners of the existing Lycopodiums and Selaginellas. The discovery of the Sphenophyllaceæ seems to throw some further light upon the phylogeny of these two groups, inasmuch as these plants possess characters which indicate affinity with both the Equisetinæ and the Lycopodinæ, thus suggesting the possibility that they may have sprung from the same ancestral stock.

To complete the geological survey of the vegetable kingdom I will briefly allude to the Bryophyta and the Thallophyta. Owing no doubt to their delicate texture, the records of these plants have been found to be very incomplete. So much is this the case with the Bryophyta that I forbear to make any statement concerning them. The chief point of interest with regard to the Fungi is that most of those which have been discovered in the fossil state were found in the tissues of woody plants on which they were parasitic. In this way it has been possible to ascertain, with some probability, the existence of Bacteria and of mycelial Fungi in the Palæozoic period. The records of the Algæ are more satisfactory: they have been traced far back into the Palæozoic age, where they are represented by siphonaceous forms and by the somewhat obscure plants known as *Nematophycus* and *Pachytheca*.

In a general way the study of Palæobotany has proved the development of higher from lower forms in the successive geological periods. Thus the Tertiary and Quaternary periods are characterised by the predominance of Angiosperms, just as the Mesozoic period is characterised by the predominance of Gymnosperms, and the Palæozoic by the predominance of Pteridophyta. And yet, as I have been pointing out, we are not able to trace the ancestry of any one of the larger groups of plants. The chief reason for this is that the geological record, so far as it is known, has been found to break off with such surprising abruptness that the earliest, and therefore the most interesting, chapters in the evolution of plants are closed to us. After the wealth of plant-forms in the Carboniferous epoch there is a striking falling-off in the Devonian, in which, however, plants of high organisation, such as the Cordaitaceæ, the Calamariaceæ, and the Lepidodendraceæ, still occur. In the Silurian epoch vascular plants are but sparingly present —but it is remarkable that any such highly organised plants should be found there—together with probable Algæ, such as *Nematophycus* and *Pachytheca*. The Cambrian rocks present nothing but so-called 'Fucoids,' such as *Eophyton*, &c., some of which may be Algæ. The only known fossil in the oldest strata of all, the Archæan, is the much-discussed *Eozoon canadense*, probably of animal origin; but the occurrence here of large deposits of graphite seems to indicate the existence of a considerable flora which has, unfortunately, become quite undeterminable. Thus, whilst there is some evidence that the primitive plants were Algæ, there is at present no available record of the various stages through which the Silurian and Devonian vascular plants were evolved from them.

Morphology.

If inquiry be made as to the cause of the great advance in the recognition of the true affinities of plants, and consequently in their classification, which distinguishes the nineteenth century, I would refer it to the progress made in the study of morphology. The earlier botanists regarded all the various parts of plants as 'organs' in relation to their supposed function; hence their description of plants was simply 'organography.' The idea of regarding the parts of the plant-body, not in connection with their functions, but with reference to their development and their mutual relations, seems to have originated with Jung in the seventeenth century (1687): it was revived by C. F. Wolff about seventy years later (1759), but it did not materially affect the study of plants until well on in the nineteenth century, after Goethe had repeatedly written on the subject and had devised the term 'morphology' to designate it. For a time this somewhat abstract mode of treatment led to mere theorising and speculation, so much so that the years 1820–1840 will always be stigmatised as the period of the 'Naturphilosophie.' But fortunately this time of barrenness was succeeded by a veritable renascence. Robert Brown and Henfrey in England; Brongniart, St. Hilaire, and Tulasne in France; Mohl, Schleiden, Naegeli, A. Braun, and, above all, Hofmeister in Germany, led the way back from the pursuit of fantastic will-o'-the-wisps to the observation of actual fact. Instead of evolving schemes out of their own internal consciousness as to how plants ought to be constructed, they endeavoured to discover by the study of development, and more particularly of embryogeny, how they actually are constructed, with the result that within a decade Hofmeister discovered the alternation of generations in the higher plants; a discovery which must ever rank as one of the most brilliant triumphs of morphological research.

With the knowledge thus acquired it became possible to determine the true relations of the various parts of the plant-body; to distinguish these parts as 'members' rather than as 'organs;' in a word, to establish homologies where hitherto only analogies had been traced—which is the essential difference between morphology and organography.

The publication of the 'Origin of Species' profoundly affected the progress of morphology, as of all branches of biological research: but it did not alter its trend; it confirmed and extended it. We are not satisfied now with establishing homologies, but we go on to inquire into the origin and phylogeny of the members of the body. In illustration I may briefly refer to two problems of this kind which at the present time are agitating the botanical world. The first is as to the origin of the alternation of generations. Did it come about by the modification of the sexual generation (gametophyte) into an asexual (sporophyte); or is the sporophyte a new formation intercalated into the life-history? In a word, is the alternation of generations to be regarded as homologous or as antithetic? I am not rash enough to express any opinion on this controversy; nor is it necessary that I should do so, since the subject has twice been threshed out at recent meetings of this Section. The second problem is as to the origin of the sporophylls, and, indeed, of all the various kinds of leaves of the sporophyte in the higher plants. It is suggested, on the one hand, that the sporophylls of the Pteridophyta have arisen by gradual sterilisation and segmentation from an unsegmented and almost wholly reproductive body, represented in our day by the sporogonium of the Bryophyta; and that the vegetative leaves have been derived by further sterilisation from the sporophylls. On the other hand, it is urged that the vegetative leaves are the more primitive, and that the sporophylls have been derived from them. It will be at once observed that this second problem is intimately connected with the first. The sterilisation theory of the origin of leaves is a necessary consequence of the antithetic view of the alternation of generations; whilst the derivation of sporophylls from foliage-leaves is similarly associated with the homologous view. Here, again, exercising a wise discretion, I will only venture to express my appreciation of the important work which has been done in connection with this controversy—work that will be equally valuable, whatever the issue may eventually be.

I will conclude my remarks on morphology with a few illustrations of the aid which the advance in this department has given to the progress of classification. For instance, Linnæus divided plants into Phanerogams and Cryptogams, on the ground that in the former the reproductive organs and processes are conspicuous, whereas in the latter they are obscure. In view of our increased knowledge of Cryptogams this ground of distinction is no longer tenable; whilst still recognising the validity of the division, our reasons for doing so are altogether different. For us, Phanerogams are plants which produce a seed; Cryptogams are plants which do not produce a seed. Again, we distinguish the Pteridophyta and the Bryophyta from the Thallophyta, not on account of their more complex structure, but mainly on the ground that the alternation of generations is regular in the two former groups, whilst it is irregular or altogether wanting in the latter. Similarly the essential distinction between the Pteridophyta and the Bryophyta is that in the former the sporophyte, in the latter the gametophyte, is the preponderating form. It has enabled us further to correct in many respects the classifications of our predecessors by altering the systematic position of various genera, and sometimes of larger groups. Thus the Cycadaceæ have been removed from among the Monocotyledons, and the Coniferæ from among the Dicotyledons, where de Candolle placed them, and have been united with the Gnetaceæ into the sub-class Gymnospermæ. The investigation of the development of the flower, in which Payer led the way, and the elaboration of the floral diagram which we owe to Eichler, have done much, though by no means all, to determine the affinities of doubtful Angiosperms, especially among those previously relegated to the lumber-room of the Apetalæ.

Anatomy and Histology.

Passing now to the consideration of the progress of knowledge concerning the structure of plants, the most important result to be chronicled is the discovery that the plant-body consists of living substance indistinguishable from that of which the body of animals is composed. The earlier anatomists, whilst recognising the cellular structure of plants, had confined their attention to the examination of the cell-walls, and described the contents as a watery or mucilaginous sap, without determining where or what was the seat of life. In 1831 Robert Brown discovered the nucleus of the cell, but there is no evidence that he regarded it as living. It was not until the renascence of research in the forties, to which I have already alluded, that any real progress in this direction was made. The cell-contents were especially studied by Naegeli and by Mohl, both of whom recognised the existence of a viscous substance lining the wall of all living cells as a 'mucous layer' or 'primordial utricle,' but differing chemically from the substance of the wall by being nitrogenous: this they regarded as the living part of the cell, and to it Mohl (1846) gave the name 'protoplasm,' which it still bears. The full significance of this discovery became apparent in a somewhat roundabout way. Dujardin, in 1835, had described a number of lowly organisms, which he termed Infusoria, as consisting of a living substance, which he called 'sarcode.' Fifteen years later, in a remarkable paper on *Protococcus pluvialis*, Cohn drew attention to the similarity in properties between the 'sarcode' of the Infusoria and the living substance of this plant, and arrived at the brilliant generalisation that the 'protoplasm' of the botanists and the 'sarcode' of the zoologists are identical. Thus arose the great conception of the essential unity of life in all living things, which, thanks to the subsequent labours of such men as de Bary, Brücke, and Max Schultze, in the first instance, has become a fundamental canon of Biology.

A conspicuous monument of this period of activity is the cell-theory propounded by Schwann in 1839. Briefly stated, Schwann's theory was that all living bodies are built up of structural units which are the cells: each cell possesses an independent vitality, so that nutrition and growth are referable, not to the organism as a whole, but to the individual cells. This conception of the structure of plants was accepted for many years, but it has had to give way before the advance of anatomical knowledge. The recognition of cell-division as the process

by which the cells are multiplied—in opposition to the Schleidenian theory of free cell-formation—early suggested doubts as to the propriety of regarding the body as being built up of cells as a wall is built of bricks. Later the minute study of the Thallophyta revealed the existence of a number of plants, such as the Myxomycetes, the phycomycetous Fungi, and the siphonaceous Algæ, some of them highly organised, the vegetative body of which does not consist of cells. It became clear that cellular structure is not essential to life; that it may be altogether absent or present in various degree. Thus in the higher plants the protoplasm is segmented or septated by walls into uninucleate units or 'energids' (Sachs), and such plants are well described as 'completely septate.' But in others, such as the higher Fungi and certain Algæ (e.g., *Cladophora, Hydrodictyon*), the protoplasm is septated, not into energids, but into groups of energids, so that the body is 'incompletely septate.' Finally there are the Thallophyta already enumerated, in which there is complete continuity of the protoplasm: these are 'unseptate.' Moreover, even when the body presents the most complete cellular structure, the energids are not isolated, but are connected by delicate protoplasmic fibrils traversing the intervening walls; a fact which is one of the most striking discoveries in the department of histology. This was first recognised in the sieve-tubes by Hartig (1837); then by Naegeli (1846) in the tissues of the Florideæ. After a long period of neglect the matter was taken up once more by Tangl (1880), when it attracted the attention of many investigators, as the result of whose labours, especially those of Mr. Gardiner, the general and perhaps universal continuity of the protoplasm in cellular plants has been established. Hence the body is no longer regarded as an aggregate of cells, but as a more or less septated mass of protoplasm: the synthetic standpoint of Schwann has been replaced by one as distinctively analytic.

Time does not permit me to do more than mention the important discoveries made of late years, mainly on the initiative of Strasburger, with regard to the details of cytology, and especially to the structure of the nucleus and the intricate dance of the chromosomes in karyokinesis. Indeed, I can do but scant justice to those anatomical discoveries which are of more exclusively botanical interest. One important generalisation which may be drawn is that the histological differentiation of the plant proceeds, not in the protoplasm, as in the animal, but in the cell-wall. It is remarkable, on the one hand, how similar the protoplasm is, not only in different parts of the same body, but in plants of widely different affinities; and, on the other, what diversity the cell-wall offers in thickness, chemical composition, and physical properties. In studying the differentiation of the cell-wall the botanist has received valuable aid from the chemist. Research in this direction may, in fact, be said to have begun with Payen's fundamental discovery (1844) that the characteristic and primary chemical constituent of the cell-wall is the carbohydrate which he termed cellulose.

The amount of detailed knowledge as to the anatomy of plants which has been accumulated during the century by countless workers, among whom Mohl, Naegeli, Unger, and Sanio deserve special mention as pioneers, is very great—so great, indeed, that it seemed as if it must remain a mere mass of facts in the absence of any recognisable general principles which might serve to marshal the facts into a science. The first step towards a morphology of the tissues was Hanstein's investigation of the growing point of the Phanerogams (1868), and his recognition therein of the three embryonic tissue-systems. This has lately been further developed by the promulgation of van Tieghem's theory of the stele, which is merely the logical outcome of Hanstein's distinction of the plerome. It has thus become possible to determine the homologies of the tissue-systems in different plants and to organise the facts of structure into a scientific comparative anatomy. It has become apparent that, in many cases, differences of structure are immediately traceable to the influence of the environment; in fact, the study of physiological or adaptive anatomy is now a large and important branch of the subject.

The study of Anatomy has contributed in some degree to the progress of systematic Botany. It is true that some of the more ambitious attempts to base classification on Anatomy have not been successful; such, for instance, as de Candolle's subdivision of Phanerogams into Exogens and Endogens, or the subdivision

of Cormophyta into Acrobrya, Amphibrya, and Acramphibrya, proposed by Unger and Endlicher. Still it cannot be denied that anatomical characters have been found useful, if not absolutely conclusive, in suggesting affinities, especially in the determination of fossil remains. A large proportion of our knowledge of extinct plants, to which I have already alluded, is based solely upon the anatomical structure of the vegetative organs; and although affinities inferred from such evidence cannot be regarded as final, they suffice for a provisional classification until they are confirmed or disproved by the discovery and investigation of the reproductive organs.

Physiology.

The last branch of botanical science which I propose to pass in review is that of physiology. We may well begin with the nutritive processes. At the close of the eighteenth century there was practically no coherent theory of nutrition; such as it was it amounted to little more than the conclusion arrived at by van Helmont a century and a half earlier, that plants require only water for their food, and are able to form from it all the different constituents of their bodies. It is true that the important discovery had been made and pursued by Priestley (1772), Ingen-Housz (1780), and Sénébier (1782) that green plants exposed to light absorb carbon dioxide and evolve free oxygen; but this gaseous interchange had not been shown to be the expression of a nutritive process. At the opening of the nineteenth century (1804) this connection was established by de Saussure, in his classical 'Recherches Chimiques,' who demonstrated that, whilst absorbing carbon dioxide and evolving oxygen, green plants gain in dry weight; and he further contributed to the elucidation of the problem of nutrition by showing that, whilst assimilating carbon dioxide, green plants also assimilate the hydrogen and oxygen of water.

Three questions naturally arose in connection with de Saussure's statement of the case: What is the nature of the organic substance formed? What is the function of the chlorophyll? What is the part played by light? It was far on in the century before answers were forthcoming.

With regard to the first of these questions the researches of Boussingault (1864) and others established the fact that the volume of carbon dioxide absorbed and that of oxygen evolved in connection with the process are approximately equal. Further, the frequent presence of starch in the chloroplastids, to which Mohl first drew attention (1837), was subsequently found by Sachs (1862) to be closely connected with the assimilation of carbon dioxide. The conclusion drawn from these facts is that the gain in dry weight accompanying the assimilation of carbon dioxide is due to the formation, in the first instance, of organic substance having the composition of a carbohydrate; a conclusion which may be expressed by the equation

$$CO_2 + H_2O = CH_2O + O_2.$$

The questions with regard to chlorophyll and to light are so intimately connected that they must be considered together. The first step towards their solution was the investigation of the relative activity of light of different colours, originally undertaken by Sénébier (1782) and subsequently repeated by Daubeny (1836), with the result that red and orange light was found to promote assimilation in a higher degree than blue or violet light. Shortly afterwards Draper (1843), experimenting with an actual solar spectrum, concluded that the most active rays are the orange and yellow; a conclusion which was generally accepted for many years. But in the meantime the properties of the green colouring matter of plants (to which Pelletier and Caventou gave the name 'chlorophyll' in 1817) were being investigated. Brewster discovered in 1834 that an alcoholic extract of green leaves presents a characteristic absorption spectrum; but many years elapsed before any attempt was made to connect this property with the physiological activity of chlorophyll. It was not until 1871–72 that Lommel and N. J. C. Müller pointed out that the rays of the spectrum which are most completely absorbed by chlorophyll are just those which are most efficient in the assimilation of carbon dioxide. Subsequent researches, particularly those of Timiriazeff (1877), and those of Engel-

mann (1882–84) based on his ingenious Bacterium-method, have confirmed the views of Lommel and of Müller, and have placed it beyond doubt that the importance of light in the assimilatory process is that it is the form of kinetic energy necessary to effect the chemical changes, and that the function of chlorophyll is to serve as the means of absorbing this energy and of making it available for the plant.

These are perhaps the most striking discoveries in relation to the nutrition of plants, but there are others of not less importance to which brief allusion must be made. We owe to de Saussure (1804) the first clear demonstration of the fact that plants derive an important part of their food from the soil; but the relative nutritive value of the inorganic salts absorbed in solution was not ascertained until Sachs (1858) reintroduced the method of water-culture which had originated centuries before with Woodward (1699) and had been practised by Duhamel (1768) and de Saussure. Special interest centres around the question of the nitrogenous nutrition of plants. It was long held, chiefly on the authority of Priestley and of Ingen-Housz, and in spite of the contrary opinion expressed by Sénébier, Woodhouse (1803), and de Saussure, that plants absorb the free nitrogen of the atmosphere by their leaves. This view was not finally abandoned until 1860, when the researches of Boussingault and of Lawes and Gilbert deprived it of all foundation. Since then we have learned that the free nitrogen of the air can be made available for nutrition—not indeed directly by green plants themselves, but, as Berthelot and Winogradsky more especially have shown, by Bacteria in the soil, or, as apparently in the Leguminosæ, by Bacteria actually enclosed in the roots of the plants with which they live symbiotically.

We turn now from the nutritive or anabolic processes to those which are catabolic. The discovery of the latter, just as of the former, was arrived at by the investigation of the gaseous interchange between the plant and the atmosphere. In the eighteenth century Scheele and Priestley had found that, under certain circumstances, plants deteriorate the quality of air; but it is to Ingen-Housz that we owe the discovery that plants, like animals, respire, taking in oxygen and giving off carbon dioxide. And when Sénébier (1800) had ascertained for the inflorescence of *Arum maculatum*, and later de Saussure (1822) for other flowers, that active respiration is associated with an evolution of heat, the connection between respiration and catabolism was established for plants as it had been long before by Lavoisier (1777) in the case of animals.

Among the catabolic processes which have been investigated none are of greater importance than those which are designated by the general term *fermentations*. The first of these to be discovered was the alcoholic fermentation of sugar. Towards the end of the seventeenth century Leeuwenhoek had detected minute globules in fermenting wort; and a century later Lavoisier had ascertained that the chemical process consists in the decomposition of sugar into alcohol and carbon dioxide; but it was not until 1837–38 that, almost simultaneously, Cagniard de Latour, Schwann, and Kützing discovered that Leeuwenhoek's globules were living organisms, and were the cause of the fermentation. Shortly before, in 1833, Payen and Persoz extracted from malt a substance named *diastase*, which they found could convert the starch of the grain into sugar. These two classes of bodies, causing fermentative changes, were distinguished respectively as *organised* and *unorganised* ferments. The number of the former was rapidly added to by the investigation more especially of the Bacteria, in which Pasteur led the way. The extension of our knowledge of the unorganised ferments, or enzymes, has been even more remarkable: we now know that very many of the metabolic processes are effected by various enzymes, such as those which convert the more complex carbohydrates into others of simpler constitution (diastase, cytase, glucase, inulase, invertase); those which decompose glucosides (emulsin, myrosin, &c.); those which act on proteids (trypsins) and on fats (lipases); the oxidases, which cause the oxidation of various organic substances; and the zymase, recently extracted from yeast, which causes alcoholic fermentation.

The old distinction of the micro-organisms as 'organised ferments' is no longer tenable; for, on the one hand, certain of the chemical changes which they effect can be traced to extractable enzymes which they produce; and, on the other, as

Pasteur has asserted, every living cell may become an 'organised ferment' under appropriate conditions. The distinction now to be drawn is between those processes which are due to enzymes and those directly effected by living protoplasm. Many now definitely included in the former class were, until lately, regarded as belonging to the latter; and no doubt future investigation will still further increase the number of the former at the expense of the latter.

The consideration of the metabolic processes leads naturally to that of the function of transpiration and of the means by which water and substances in solution are distributed in the plant. This is perhaps the department of physiology in which progress during the nineteenth century has been least marked. We have got rid, it is true, of the old idea of an ascending crude sap, and of a descending elaborated sap, but there have been no fundamental discoveries. With regard to transpiration itself, we know more of the detail of the process, but that is all that can be said. As for root-pressure, Hofmeister (1858-62) discovered that 'bleeding'—as the phenomena of root-pressure were termed by the earlier writers—is not confined, as had hitherto been thought, to trees and shrubs; but the current theory of the process, allowing for the discovery of protoplasm and of osmosis, has advanced but little upon that given by Grew in the third book of his 'Anatomy of Plants' (1675). Again, the mechanism of the transpiration-current in lofty trees remains an unsolved problem. To begin with, there is still some doubt as to the exact channel in which the current travels. Knight (1801-8) first proved that the current travels in the alburnum of the trunk, but not, he thought, in the vessels, for he found them to be dry in the summer, when transpiration is most active; a view in which Dutrochet (1837) subsequently concurred. Meyen (1838) then suggested that the water must travel, not in the lumina, but in the substance of the cells of the vessels, and was supported by such eminent physiologists as Hofmeister (1858), Unger (1864, 1868), and Sachs (1878); but it has since been strongly asserted by Boehm, Elfving, Vesque, Hartig, and Strasburger that the young vessels always contain water, and that the current travels in the lumina and not in the walls of the vessels.

Now as to the force by which the water of the transpiration-current is raised from the roots to the topmost leaf of a lofty tree. From the point of view that the water travels in the substance of the walls the necessary force need not be great, and would be amply provided by the transpiration of the leaves, inasmuch as the weight of the water raised would be supported by the force of imbibition of the walls. From the point of view that the water travels in the lumina the force required to raise and support such long columns of water must be considerable. Dismissing at once as quite inadequate such purely physical theories as those of capillarity and gas-pressure, there remain two theories as to the nature of this force which resemble each other in being essentially vitalistic, but differ in that the one involves pressure from below, the other suction from above. In the one, suggested by Godlewski and by Westermaier (1884), the cells of the medullary rays and of the wood-parenchyma are supposed to absorb liquid from the vascular tissue at one level and force it back again by a vital act at a higher level: this theory was disposed of by the fact that the transpiration-current can be maintained through a considerable length of a stem killed by heat or by poison. In the other, suggested by Dixon and Joly (1895–99), and also by Askenasy (1895–96), it is assumed that there are, in the trunk of a transpiring tree, continuous columns of water which are in a state of tensile stress, the tension being set up by the vital transpiratory activity of the leaves. Some idea of the enormous tension thus assumed is given by the following simple calculation relating to a tree 120 feet high. Not only has the liquid to be raised to this height, but in its passage upwards a resistance calculated to be equal to about five times the height of the tree has to be overcome. Hence the transpiration-force in such a tree must at least equal the weight of a column of water 720 feet in height; that is, a pressure of about twenty-four atmospheres, or 360 lb. to the square inch. But there is no evidence to prove that a tension of anything like twenty atmospheres exists, as a matter of fact, in a transpiring tree; on the contrary, such observations as exist (*e.g.*, those of Hales and of Boehm) indicate much lower tensions. Under these circumstances we must regretfully confess that yet

one more century has closed without bringing the solution of the secular problem of the ascent of the sap.

The nineteenth century has been, fortunately, rather more fertile in discovery concerning the movements and irritability of plants. But it is surprising how much knowledge on these points had been accumulated by the beginning of the century: the facts of plant-movement, such as the curvatures due to the action of light, the sleep-movements of leaves and flowers, the contact-movements of the leaves of the sensitives, were all familiar. The nineteenth century opened, then, with a considerable store of facts; but what was lacking was an interpretation of them; and whilst it has largely added to the store, its most important work has been done in the direction of explanation.

The first event of importance was the discovery by Knight, in 1806, of the fact that the stems and roots of plants are irritable to the action of gravity and respond to it by assuming definite directions of growth. Many years later the term 'geotropism' was introduced by Frank (1868) to designate the phenomena of growth as affected by gravity, and at the same time Frank announced the important discovery that dorsiventral members, such as leaves, behave quite differently from radial members, such as stems and roots, in that they are diageotropic.

It was a long time before the irritability of plants to the action of light was recognised. Chiefly on the authority of de Candolle (to whom we owe the term 'heliotropism'), heliotropic curvature was accounted for by assuming that the one side received less light than the other, and therefore grew the more rapidly. But the researches of Sachs (1873) and Müller-Thurgau (1876) have made it clear that the direction of the incident rays is the important point, and that a radial stem, obliquely illuminated, is stimulated to curve until its long axis coincides with the incident rays. Moreover, the discovery by Knight (1812) of negative heliotropism in the tendrils of *Vitis* and *Ampelopsis* really put the Candollean theory quite out of court; and further evidence that heliotropic movements are a response to the stimulus of the incident rays of light is afforded by Frank's discovery of the diaheliotropism of dorsiventral members.

The question of the localisation of irritability has received a good deal of attention. The fact that the under surface of the pulvinus of *Mimosa pudica* is alone sensitive to contact was ascertained by Burnett and Mayo in 1827; and shortly after (1834) Curtis discovered the sensitiveness of the hairs on the upper surface of the leaf of *Dionæa*. After a long period of neglect the subject was taken up by Darwin. The irritability of tendrils to contact had been discovered by Mohl in 1827; but it was Darwin who ascertained, in 1865, that it is confined to the concavity near the tip. In 1875 Darwin found that the irritability of the tentacles of *Drosera* is localised in the terminal gland; and followed this up, in 1880, by asserting that the sensitiveness of the root is localised in the tip, which acts like a brain. This assertion led to a great deal of controversy, but the researches of Pfeffer and Czapek (1894) have finally established the correctness of Darwin's conclusion. It is interesting to recall that Erasmus Darwin had suggested the possible existence of a brain in plants in his 'Phytologia' (1800). But the word 'brain' is misleading, inasmuch as it might imply sensation and consciousness: it would be more accurate to speak of centres of ganglionic activity. However, the fact remains that there exist in plants irritable centres which not only receive stimuli but transmit impulses to those parts by which the consequent movement is effected. The transmission of stimuli has been found in the case of *Mimosa pudica* to be due to the propagation of a disturbance of hydrostatic equilibrium along a special tissue; in other cases, where the distance to be traversed is small, it is probably effected by means of that continuity of the protoplasm to which I have already alluded.

Finally, as regards the mechanism of these movements, we find Sénébier and Rudolphi, the earliest writers on the subject in the nineteenth century, asserting, as if against some accepted view, that there is no structure in a plant comparable with the muscle of an animal. Rudolphi (1807) suggested, as an alternative, that the position of a mobile leaf is determined by the 'turgor vitalis' of the pulvinus, and thus anticipated the modern theory of the mechanism. But he gives no

explanation of what he means by 'turgor;' and the term is frequently used by writers in the first half of the century in the same vague way. Some progress was made in consequence of the discovery of osmosis by Dutrochet (1828), and more especially by his observation (1837) that the movements of *Mimosa* are dependent on the presence of oxygen, and are therefore vital. But it was not, and could not be, until the existence of living protoplasm in the cells of plants was realised, and the movements of free-swimming organisms and naked reproductive cells had become more familiar, that the true nature of the mechanism began to be understood; and then we find Cohn saying, as long ago as 1860, that 'the living protoplasmic substance is the essentially contractile portion of the cell.' This statement may, perhaps, seem to put the case too bluntly and to savour too much of animal analogy; but the study of the conditions of turgidity has shown more and more clearly that the protoplasm is the predominant factor. The protoplasm of plant-cells is undoubtedly capable of rapid molecular changes, which alter its physical properties, more particularly its permeability to the cell-sap. It may be that these changes cannot be directly compared with those going on in animal muscle; but if we use the term 'contractility' in its wider sense, as indicating a general property of which muscular contraction is a special case, then Cohn's statement is fully justified. This is borne out by the observations of Sir J. Burdon-Sanderson (1882–88) on the electrical changes taking place in the stimulated leaf of *Dionæa*, and by Kunkel's (1878) corresponding observations on *Mimosa pudica*: in both cases the electrical changes were found to be essentially the same as those observable on the stimulation of muscle. We find, then, that the advances in Physiology, like those in Anatomy, teach the essential unity of life in all living things, whether we call them animals or plants.

With this in our minds we may go on to consider in conclusion, and very briefly, that department of physiological study which is known as the Bionomics or Œcology of plants. In the earlier part of the century this subject was studied more especially with regard to the distribution of plants, and their relation to soil and climate: but since the publication of the 'Origin of Species' the purview has been greatly extended. It then became necessary to study the relation of plants, not only to inorganic conditions, but to each other and to animals; in a word, to study all the adaptations of the plant with reference to the struggle for existence. The result has been the accumulation of a vast amount of most interesting information. For instance, we are now fairly well acquainted with the adaptations of water-plants (hydrophytes) on the one hand and of desert-plants (xerophytes) on the other; with the adaptations of shade-plants and of those growing in full sun, especially as regards the protection of the chlorophyll. We have learned a great deal as to the relations of plants to each other, such as the peculiarities of parasites, epiphytes, and climbing plants, and as to those singular symbioses (Mycorhiza) of the higher plants with Fungi which have been found to be characteristic of saprophytes. Then, again, as to the relations between plants and animals: the adaptation of flowers to attract the visits of insects, first discovered by Sprengel (1793), has been widely studied; the protection of the plant against the attacks of animals, by means of thorns and spines on the surface, as also by the formation in its tissues of poisonous or distasteful substances, and even by the hiring of an army of mercenaries in the form of ants, has been elucidated; and finally those cases in which the plant turns the tables upon the animal, and captures and digests him, are now fully understood.

Conclusion.

Imperfect as is the sketch which I have now completed, it will, I think, suffice to show how remarkable has been the progress of the science during the nineteenth century, more particularly the latter part of it, and how multifarious are the directions in which it has developed. In fact Botany can no longer be regarded as a single science: it has grown and branched into a congeries of sciences. And as we botanists regard with complacency the flourishing condition

of the science whose servants we are, let us not forget, on the one hand, to do honour to those whose lifework it was to make the way straight for us, and whose conquests have become our peaceful possession; nor, on the other, that it lies with us so to carry on the good work that when this Section meets a hundred years hence it may be found that the achievements of the twentieth century do not lag behind those of the nineteenth.

The following Reports and Papers were read:—

1. *Report on Experimental Investigation of Assimilation in Plants.* See Reports, p. 569.

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2. *Report on Fertilisation in the Phæophyceæ.*—See Reports, p. 569.

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3. *British Sylviculture. By* Samuel Margerison.

Former supplies and high quality of British oak, &c. Recent supplies largely consist of foreign timber. Native timbers still required in large quantities and likely to be more in demand, because of lessening of stocks and enlarged home consumption in the countries now supplying us. The period covered by the life of a timber-tree fruitful in economic changes. We have much land at present unproductive, or only slightly productive, suitable for growing a native supply of timber, but owners and nation comfortably apathetic in the matter, content with present abundant supply. Sportsmen are groundlessly fearful of their pleasures being disturbed. It is really a national matter, calling for Government aid and *supervision*, or good private 'working plans,' which cannot be disturbed by changes of individual management.

Comparison of results of Continental sylviculture with ours; their crops treble and quadruple of ours. Natural conditions here not less favourable, but management generally inferior.

Differences arise in details:

Growing the Crop.—Thick planting and careful thinning (preserving an overhead canopy and encouraging lengthy growth); making sport secondary to sylviculture, whilst still providing abundance of it.

Harvesting the Crop.—Gradual thinning; reserving the thriving trees; partial conversion on the spot; savings in haulage, again keeping sport secondary; reasonable cost of railway carriage. Forestry schools, with opportunities for detailed research and teaching, with equipment, scientific and practical, worthy of the subject.

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4. *The Great Smoke-Cloud of the North of England and its Influence on Plants. By* Albert Wilson.

The widespread effect of smoke insufficiently realised. Dwellers in towns often so hardened to it as to be almost oblivious of its presence. The great smoke-producing district of the North of England; its extent; miserable condition of vegetation in some parts of the area. Variation in amount of smoke according to the season. Effect in reducing air transparency; dimness of sky and landscape. Distance to which smoke travels. Smoke often mistaken for haze. Red sunsets in South-east Yorkshire. Atmosphere of the North of England. North of the smoke area never brilliant with southerly winds. The smoke from Barrow-in-Furness, an isolated town; long distance at which this is noticeable; comparison of its volume with that from the great smoke area. The characteristic smell from certain large works, and the distance at which it can be detected. Discoloration of rainwater; 'black rain.' Influence of smoke on sunshine and air temperature in calm summer weather, and in anticyclonic weather during autumn or winter;

low day-temperature maxima. Smoke and fog-production. Long-continued smoke fog of February 1891. Darkness in and around large cities. Effect of smoke on mosses and hepatics as compared with that on higher plants. Smoke at a maximum in winter, when many mosses are in a vegetative condition. Great diminution in their abundance and luxuriousness in the neighbourhood of large towns. Peculiar exposure of bark-loving species to smoke influence, and the cause. Threatened extinction of *Ulota* and *Orthotricha*.

5. *A Gymnosporangium from China. By* F. E. Weiss.

This fungus was first observed by Dr. A. G. Parrott in the spring of 1899 in Lao-ho-kou, in North Central China (lat. 32° 50′ N., long. 112° E.). Its spore masses made their appearance in April on the branches of *Juniperus chinensis* in the form of bright yellow gelatinous masses after a few days' continuous rain. The teleutospore-beds appear singly or in clusters on the leaves of the smaller branches, usually in more or less flat leaf-like masses. When close together they often become confluent. The teleutospores are of the usual type, two-celled, tapering towards both ends and somewhat rounded at the apex. They possess eight germ pores.

What is in all probability the Rœstelia stage of this fungus was observed during the summer on the leaves of the pear, *Pyrus sinensis*, Ldl. A tree of this species growing in proximity to the infected junipers was attacked by a fungus of the Rœstelia type, producing typical æcidiospores.

In the appearance of its teleutospore masses and in the shape and structure of the *teleuto*spores this fungus appears most nearly related to *Gymnosporangium Sabinæ* (Dicks), a widely distributed form occurring in Europe and in America, and to *Gymnosporangium Cunninghamianum* (Barclay), a Himalayan form, both of which have their Rœstelia stage on a pear, the former on *Pyrus communis*, the latter on *Pyrus Pashia.*

6. *Demonstration of the Structure and Attachment of the Flagellum in* Euglena viridis. *By* Harold Wager.

The flagellum of *Euglena viridis* possesses a bifurcate base, which is attached to the wall of the excretory reservoir at the anterior end of the body.[1] As it passes to the anterior, through the gullet, an enlargement occurs in the region of, and partly surrounded by, the eye-spot. This structure can be seen in very favourable cases in the living condition, but usually only after the action of reagents. The best reagent for this purpose is either a 1 per cent. solution of osmic acid or a 2 per cent. solution of bichromate of potash with a 1 per cent. solution of osmic acid. Good preparations have also been obtained by treating fresh cells with a solution of iodine.

The structure may be obscured by small grains of paramylon which sometimes accumulate at the anterior end of the body.

7. *On the Structure of the Root-nodules of* Alnus glutinosa. *By* T. W. Woodhead..

Longitudinal sections show that the nodule is traversed by a central strand of short, thick-walled, prosenchymatous fibres, with transverse pits in the walls. Surrounding this are four or five layers of cubical cells, rich in protoplasm, followed by a small-celled bulky cortex. On the outside of this is a phellogen, which produces a layer of cork several cells deep. The cortical cells are largely occupied by the organism which produces the nodule. Their distribution is roughly in parallel layers of cells passing obliquely from the central strand outwards; between

[1] See Wager, *Journal Linn. Soc. Zoology*, vol. xxvii. p. 463.

these layers are cells filled with starch grains, often in various stages of disorganisation, embedded in a very granular protoplasm, much resembling bacteria.

The organism is usually present as a globular sporangium at the end of a short hypha: these bodies are densely packed within the cells; their life-history, though as yet obscure, presents several different phases. Towards the base of the nodule are strands of cells occupied by disorganised contents indicating a previous tract of growth of the organism: this is succeeded by groups of cells filled with the organism in various stages. Towards the apex, and immediately behind the growing point, the cells containing the sporangia are immediately followed by cells filled with fine hyphal filaments which may be seen to penetrate the walls of the young adjacent cells.

These observations, which are as yet in a preliminary stage, were made in the Botanical Laboratory, Cambridge, through the kindness of Professor H. Marshall Ward, to whom I am greatly indebted for much help and encouragement.

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8. *Fungi found in Ceylon growing upon Scale-insects* (Coccidæ *and* Aleurodidæ).[1] *By* J. PARKIN, *M.A., Trinity College, Cambridge.*

The author's attention was called to these fungi by Mr. E. E. Green, Entomologist to the Government of Ceylon. The greater part of the specimens was supplied by him. A few examples were collected by the author.

Fungi associated with scale-insects have till recently been little studied. A few species have been mentioned from time to time as growing upon scales of dead coccids, but, till within the last few years, hardly any attention has been called to their probable parasitic character or to the capability of their being employed to check the ravages of scale-pests. Webber[2] in 1897 points out for the first time the parasitic habit of certain species—five in all—of *Aschersonia* on scale-insects infesting the orange and other plants in Florida. Zimmermann[3] in the following year in Java gives a preliminary account of a fungus (*Cephalosporium*) attacking the green bug (*Lecanium viride*), so harmful to the coffee, and describes how it may be artificially cultivated for infecting experiments. Green is also conducting such experiments in Ceylon.

The various kinds here brought to notice are referable to the following genera:

Pyrenomycetes-Hypocreales: *Nectria, Torrubiella.*

Fungi imperfecti: *Aschersonia, Cephalosporium, Verticillium, Microcera, Campsotrichum* (?).

Nectria.—The conidial stage belongs to the *Fusarium* type, with large multiseptate curved conidia. Two distinct species are perhaps recognisable. One has been found on several occasions growing on scale-insects, belonging to three genera of the tribe Diaspidinæ. It may perhaps be identical with *N. aurantiicola*, B. and Br.,[4] which is mentioned incidentally as growing apparently from some coccus on orange twigs. The other was found on a scale (*Asterolecanium miliaris*) infesting a bamboo.

The only allusions to this habitat for Nectria that the author has found, besides the above one, are two:[5] regarding Brazilian species (*N. coccorum*, Speg., and *N. coccogena*, Speg.), both described as growing on dead cocci on leaves.

Torrubiella.—This genus, with thread-like ascospores, consists so far of only

[1] The paper was illustrated by dried specimens and coloured drawings by Mr. Wm. de Alwis, the Sinhalese draughtsman attached to the Royal Botanical Gardens, Peradeniya.

[2] Webber, 'Sooty Mold of the Orange and its Treatment,' *U.S. Depart. of Agric.: Div. of Veg. Physiol. and Pathol.*, 1897, No. 13.

[3] Zimmermann, 'Over eene Schimmelepidemie der Groene Luizen,' Voorloopig Rapport, 1898. Buitenzorg, Java.

[4] Berkeley and Broome, 'Fungi of Ceylon,' *Journ. Linn. Soc.*, xiv. 1875, p. 117.

[5] Saccardo's *Sylloge Fungorum*, Additamenta to vols. i.–iv. 1886, p. 203, and vol. ix. 1891, p. 959.

three species: one of these, *T. rubra*, Pat. and Lagerh.,[1] is described as growing on a coccus. The Ceylon forms, two in number, agree fairly closely with the description of *T. rubra*. One, with deep pink perithecia, was found on a species of *Aleurodes*, the other, with pale brown perithecia, on a species of *Aspidiotus*.

Aschersonia.—This genus, chiefly tropical, and consisting now of about nineteen species, has usually been taken to be a leaf-infesting one. Webber[2] has shown that it may also be entomogenous. It is quite possible that species hitherto regarded as growing on leaves and stems are in reality parasitic on scale-insects occurring on these parts of plants. The Ceylon forms have been formed on species of *Aleurodes* and *Lecanium*.

Along with one of these Aschersonias on the same kind of scale are flattened circular brown fungous pustules, which are similar in structure to what Webber names as the 'brown mealy-wing fungus.'[3] In neither case has any trace of spore-formation been found.

Cephalosporium.—The fungus referred to previously as found by Zimmermann on the green bug has been named by him provisionally as *Cephalosporium Lecanii*. Specimens practically identical with this have been obtained in Ceylon on the same scale on the coffee and other plants, also on two other species of *Lecanium*.

Verticillium.—The species *V. heterocladium*,[4] described by Penzig as occurring on the dead bodies of *Lecanium hesperidum* on leaves of the lemon, is the single instance found of such a habitat for this genus. The Ceylon member was discovered on the same scale and on the same bamboo as possessed the *Nectria*, mentioned above. As a rule the *Nectria* was confined to the upper and the *Verticillium* to the lower surface of the leaves. Possibly the two may be connected.

Microcera.—This genus, closely related to *Fusarium*, was established by Desmazières[5] in 1848 for a fungus (*M. coccophila*) discovered on a scale-insect. Later it was shown to be the conidial stage of *Sphærostilbe coccophila*.[6] Another species, *M. rectispora*, Cooke and Mass.,[7] has been found associated with a coccus on the orange in Australia. The Ceylon types occur on three genera of the Diaspidinæ. One of them is probably the conidial stage of a *Calonectria*.

Campsotrichum.—The fungus referred to this genus was discovered growing on a scale (*Chionaspis Aspidistræ*) on a palm. It has not yet received a very close examination, but seems to agree best with this genus of the group Dematiaceæ of the Fungi imperfecti.

Mr. Green has also passed on to the author specimens of this class of fungi received from other countries, viz., *Aschersonia* from India, Sumatra, and Java, and *Microcera* from West Africa and Mauritius.

Thus it seems that fungi infesting scale-insects have an extensive distribution, especially in and near the tropics. That they are the true cause of the death of the insects there seems little doubt.

FRIDAY, SEPTEMBER 7.

The following Papers were read:—

1. *On the so-called Optimum Strength of CO_2 for Assimilation.* *By* Dr. F. F. Blackman.

[1] Patouillard et Lagerheim, 'Sur Champignons de l'Equateur,' *Bull. de la Soc. Mycol. de France*, vol. ix. 1893, p. 154.

[2] Webber, *loc. cit.*

[3] Webber, *loc. cit.*, p. 27.

[4] Saccardo, *S.F.*, vol. iv. 1886, p. 151.

[5] Desmazières, 'Plantes Cryptogames Nouvelles,' *Ann. des Sc. Nat.*, 3rd ser., 1848, p. 359.

[6] Tulasne, *Carpologia*, vol. iii. 1865, p. 105.

[7] Saccardo, *S.F.*, vol. x. p. 731.

2. *On the Effect of the Closure of Stomata on Assimilation.* *By* Dr. F. F. BLACKMAN *and* Miss MATTHÆI.

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3. *Formation of Starch from Glycollic Aldehyde by Green Plants.* *By* HENRY JACKSON, *B.A.*, *B.Sc.*

Glycollic aldehyde or diose has recently been isolated in a crystalline state,[1] and more recently it has been shown by the author [2] that this substance, under the influence of dilute alkalis, very quickly condenses to two synthetic hexoses, one of which, and acrose, is identical with fructose

$$3C_2H_4O_2 = C_6H_{12}O_6.$$

It therefore became a matter of interest to find whether green plants could build up starch if allowed to remain for a time in a solution of this simple sugar. The following are the results of a few experiments. Leaves of *tropæolum* and clover, which had been depleted of their starch by growing in the dark, were floated in a 3 per cent. aqueous solution of diose, control experiments being made with cane sugar, glycerine, and distilled water; the whole series being kept in the dark for six days. They were then tested by Sachs's method, and it was found that those floating in pure water were quite starchless, those in glycerine almost so, but those growing in diose had accumulated starch in the tissues, though not to the same extent as those placed in cane sugar.

Spirogyra was placed in a 1 per cent. solution of diose in an atmosphere free from CO_2, and after five days in the light had accumulated starch, whilst the control experiment in distilled water showed only a small quantity of starch. In the last set of experiments *spirogyra* was grown in an atmosphere free from CO_2, but kept in the dark. After a week the control specimen, which had been in distilled water, was starchless, whilst that growing in the sugar had formed large quantities of starch.

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4. *On the Effect of Salts on the CO_2 Assimilation of* Ulva latissima, *L.* *By* E. A. NEWELL ARBER, *B.A.*

The primary object of these experiments was to obtain a general idea of the extent to which the power of CO_2 assimilation is dependent on the absorption of nutrient salts.

It was found that an inhibition of the CO_2 assimilation could be caused by the presence or absence of certain salts in the medium.

Ulva was rendered free from starch, and exposed to light in media containing known proportions of salts. The amount of CO_2 assimilation which took place was gauged by the starch accumulation. In distilled water only a very small amount of starch was formed, while in tap-water containing traces of nutrient salts the inhibition was only slight. Distilled water was not found to have any injurious effect on the plant. The presence of NaCl in the medium was found to be essential in order to obtain the maximum of CO_2 assimilation. From indirect evidence a total or almost total absence of NaCl caused a very marked inhibition in all cases; and no other salt could be found to replace NaCl in regard to CO_2 assimilation.

The absence of any one of the following salts, $MgCl_2$, $MgSO_4$, $CaSO_4$, or KCl, from sea water did not inhibit the assimilation. The presence of a nitrate in appreciable quantity in the medium caused an inhibition. Ammonium nitrate was found to be fatal. KNO_3 caused a more marked inhibition than $NaNO_3$; the inhibition being least marked in the case of $Mg(NO_3)_2$.

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[1] Fenton and Jackson, *J. Chem. Soc. Trans.*, 1899.
[2] *J. Chem. Soc. Trans.*, 1900.

5. *The Sea-weed* Ulva latissima *and its Relation to the Pollution of Sea-water by Sewage. By* Professor LETTS, *D.Sc., Ph.D., and* JOHN HAWTHORNE, *B.A., Queen's College, Belfast.*

For a number of years past a very serious nuisance has arisen from the sloblands of the upper reaches of Belfast Lough during the summer months, the stench at low tide being quite overpowering, and the air heavily charged with sulphuretted hydrogen. A precisely similar nuisance, though not of the same magnitude, also arises from the sloblands in the northern portion of Dublin Bay.

The nuisance is caused by deposits of the green sea-weed, called *Ulva latissima*, or sea-lettuce, which in the two localities mentioned grows in abundance, and during high winds or gales is washed ashore. In Belfast Lough the quantity thus deposited is enormous, forming banks which are often several feet thick, and extend for miles along the coast. Once deposited, these layers of sea-weed often remain more or less stationary for months in the shallow bays or pools of the neighbourhood, and in warm weather rapid putrefaction occurs, and a perfectly intolerable stench arises, which is perceptible over a wide area, and seriously affects not only the comfort of the inhabitants of the district, but the value of their property also.

The Chemical Changes which occur when Ulva latissima *ferments in Sea-water.*—An extended investigation in the laboratory has shown that when the sea-weed ferments hydrogen and carbonic anhydride are first evolved in about equal proportions by volume, and fatty acids are produced. Isolation and examination of these latter show that propionic acid is the chief; butyric acid is also formed, and probably acetic acid in addition. In a later stage of the fermentation sulphides are formed, probably by reduction of sulphates present in the sea-water, and the sea-weed blackens from formation of ferrous sulphide, and this latter disengages sulphuretted hydrogen by the action of the fatty acids, whence the nuisance.

Composition of Ulva latissima.—The mean results of the analysis of the dried sea-weed were as follows:—

Carbon	35·15	
Hydrogen	5·27	
Nitrogen	6·25	
Oxygen	37·96	
Ash	15·37	containing { Sulphur 3·21, Iron 2·20
	100·00	

Attempts to isolate any definite principles by the methods of proximate analysis were not very successful, and no carbohydrate beyond cellulose could be identified.

Bacteriological Examination.—Considerable difficulty was experienced in attempts to isolate the organisms concerned in the putrefactive processes, and the ordinary methods failed for the greater part. The evidence at present collected points to there being two chief species concerned. (1) A spore-forming bacillus which apparently infests the sea-weed and causes the production of fatty acids from its tissues; and (2) a second micro-organism, probably derived from the mud of the shore, which gives rise to the formation of sulphides by a later fermentative process.

Ulva latissima *in Relation to Sewage Pollution.*—The evidence tending to prove that the occurrence of the sea-weed in *quantity* in any locality is associated with sewage pollution is of three kinds.

(1) *The Composition of its Tissues.*—The amount of nitrogen it contains is far in excess of that of any other sea-weed of which analyses are recorded. It contains over 6 per cent., and resembles in nitrogen content an animal product rather than a vegetable. (Dry cheese contains about 7, and dry milk about 5 per cent., whereas peas only contain about 4 and meadow hay 2 per cent.)

(2) *Assimilation Experiments.*—A frond of the sea-weed was placed in various mixtures in succession (*a*) of polluted sea-water, (*b*) polluted sea-water *plus* sewage, (*c*) polluted sea-water with sewage and ammonium salt, (*d*) sea-water *plus* nitrates. By determinations of free and albuminoid ammonia, and nitrates in these mixtures before and after the sea-weed had been in contact with them, the power of assimilating nitrogen which the weed possesses was ascertained and was found to be remarkably high. Thus in one experiment it absorbed the *whole* of the free ammonia from a polluted sea-water containing 0·050 part per 100·000 in seventeen hours. Nitrates were also rapidly absorbed, but not albuminoid matters. The weed remained in perfect health during these experiments and is still growing, although nine months have elapsed since the experiments were commenced.

(3) *The Localities where* Ulva latissima *abounds, and from which it is virtually absent.*—As stated above the sea-weed is present in abundance in Belfast Lough, but it is almost entirely absent from Strangford Lough, which is similar in area and in many other respects to Belfast Lough, but differs from it in not being extensively polluted by sewage. In Dublin Bay the sea-weed is found in quantity in the harbour, which is highly polluted, but not in the southern parts of the bay, which receive no sewage—except near Kingstown, where a large sewage tank discharges on the ebb tide. There the weed occurs.

The evidence which the authors have collected tends therefore to the conclusion that the occurrence of *Ulva latissima* in quantity in a given locality is an indication of sewage contamination, and there can be no doubt as to the power which the weed possesses of absorbing nitrogen compounds from polluted sea-water. While thus acting as scavenger it may itself give rise to a very extensive nuisance.

6. *Germination of the Zoospore in Laminariaceæ.* *By* J. Lloyd Williams.

The zoospore comes to rest and assumes a spherical form. The single chloroplast divides in two. A tube is produced and the contents pass into it. At the end of the tube a swelling is formed, into which all the contents migrate, and are shut off from the empty spore-case and tube by a wall. This has been wrongly regarded by Areschong, in the case of *Dictyosiphon*, as a case of sexual fusion. In the enlargement the chloroplasts multiply and additional eye-spots appear on several, which, however, disappear after a few days. The newly separated cell now divides and forms a branched protonema-like structure. see p. 569

7. Professor Percy Groom delivered a Lecture on Plant-form in Relation to Nutrition.

SATURDAY, SEPTEMBER 8.

The following Papers were read:—

1. *On Double Fertilisation in a Dicotyledon*—Caltha palustris.[1] *By* Ethel N. Thomas.

This research was undertaken at Miss Sargant's suggestion, because of the extreme importance of the discovery of double fertilisation in Monocotyledons by Professor Nawaschin and later by Professor Guignard.

The work was carried out at the Royal College of Science, South Kensington, and among other plants Professor Farmer recommended *Caltha palustris.*

[1] Published in *Annals of Botany*, vol. xiv., September 1900.

The polar nuclei of this plant unite before fertilisation, but that there is no absolutely fixed period is shown by the very different appearance of sacs in which polar fusion is taking place.

The male generative nuclei, when first set free in the embryo sac, are extremely small and heavily stained. Their chromatic substance is so densely aggregated as to render the spermatozoid to all appearance homogeneous.

Of the two spermatozoids one—I believe that which leaves the pollen tube first—passes to the middle of the sac and there *fertilises the definitive nucleus*; the other fertilises the nucleus of the oosphere.

By the time the male generative nucleus or spermatozoid has reached the definitive nucleus, it has enlarged immensely, and shows a light spongy structure with scattered chromatin granules. The other spermatozoid, however, increases very little in size, and always remains dark and dense.

When the spermatozoids leave the pollen tube they are somewhat short and thick, and only slightly curved, but when the one has approached the definitive nucleus, it has the typical vermiform shape, with one or several coils.

Professor Nawaschin has recently published an account of double fertilisation in *Delphinium* and in two Composites.

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2. *The Conducting Tissues of Bryophytes.* *By* A. G. Tansley.

The most important part of our present knowledge of these tissues is due to Haberlandt,[1] who, in the Polytrichaceæ, distinguished a *hadrom* (*hydrom*) or water-conducting system from a *leptom*, conducting plastic, especially nitrogenous, substances. In the lower mosses, only the hydrom is differentiated, and in the xerophilous and hydrophilous forms, in which water is taken in at any part of the surface, even this is absent. Localisation of the region of absorption is the condition on which the evolution of a hydrom depends.

In the present investigation the lignified strand of prosenchyma in the midst of the thallus of certain Liverworts (*Pallavicinia*, *Symphyogyna* and *Hymenophyton*) was shown to be a hydrom strand, and its development to be correlated to some extent with the localisation of the absorptive region of the thallus.

The rhizome of four species of *Polytrichum* was investigated, and in every case was found to possess with striking completeness the distribution of tissues characteristic of the root of a vascular plant. The transition to the structure of the aërial stem was followed, and while the account of the structure of the latter given by previous observers was confirmed in most particulars, some new points in the structure and course of the leaf-traces were observed, and new light was, it is hoped, thrown on the constitution of the Polytrichaceous stele, which is thought to consist of two regions, primitively distinct in function and by descent. Finally, an attempt has been made to trace out the course of evolution of these conducting tissues in the Bryophytic series.

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3. *On a Fourth Type of Transition from Stem to Root-structure occurring in certain Monocotyledonous Seedlings.* *By* Ethel Sargant.

The three types of transition from a stem to a root-structure described by Professor Ph. van Tieghem ('Traité de Botanique,' 2me édition, 1891, p. 782) are briefly as follows:—

1. As the n bundles of the hypocotyledonary stele descend into the primary root, the xylem of each bundle branches to right and left at the same time that the protoxylem elements become external. The right-hand branch from each bundle unites with the left-hand branch of the adjacent one, so that we still have n xylem groups in the root-stele. The n phloem groups descend in a straight line without branching or rotation.

[1] *Beiträge zur Anatomie und Physiologie der Laubmoose*, 1886.

2. There are $2n$ bundles in the hypocotyl. As they descend into the root each bundle rotates on its axis in such a way that the phloem groups are able to unite in pairs. The xylem groups also unite in pairs, the protoxylem elements becoming external as they do so. Thus there are n phloem and n xylem groups in the root-stele.

3. There are n bundles in the hypocotyl as in type 1, but in this case each of the phloem groups divides into two without rotation. The branches from adjacent bundles unite in pairs, so that we still have n phloem groups in the stele. Meanwhile each of the xylem groups has rotated on its axis without branching. Thus the n xylem groups are all external.

It is clear that type 3 is the converse of type 1.

Among the monocotyledonous seedlings which I have examined I find a fourth type of transition, which is the converse of type 2. The best example is *Anemarrhena asphodeloides*, but there are very clear traces of the same structure in the allied genera *Asphodelus* and *Asphodeline.*

The type may be thus defined:—

4. There are n bundles in the hypocotyl. As they descend into the primary root the phloem of each divides into two groups without rotation or subsequent fusion. Thus there are $2n$ phloem groups in the root-stele. The xylem of each bundle branches in two or more directions, while the protoxylem elements become external. If more than $2n$ xylem groups have been thus formed, adjacent groups fuse in pairs, so that only $2n$ xylem groups enter the root-stele.

In *Anemarrhena asphodeloides* there are two bundles in the cotyledon which pass downwards through the hypocotyl into the primary root. During the transition each phloem group divides into two. Each xylem group branches in three directions. It sends a group of protoxylem elements to divide its own two phloem groups from each other. This we may call the median protoxylem group. Two lateral protoxylem groups are also formed from the xylem of each bundle in the space dividing the bundles from each other. The four lateral protoxylem groups thus formed are reduced to two by the fusion of adjacent groups in pairs. In the end there are four phloem groups and four protoxylem groups in the root-stele.

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4. *The Origin of Modern Cycads.* *By* W. C. Worsdell, *F.L.S.*

The subject is treated from the aspect of the vegetative structure.

An exhaustive study of the vegetative characters enables one to draw theoretical conclusions as to the origin of modern Cycads.

This conclusion is that the latter have descended directly from some Cycado-filicinean type possessing the structure exhibited especially by such forms as the Medullosæ and Lyginodendreæ, the chief point being that the collaterally constructed one or more vascular cylinders of modern Cycads have been derived from one or more *concentrically* constructed cylinders of some Cycado-filicinean form.

Those characters in the modern plants which approximate most nearly to the primitive ancestral type are found in those parts of the plant where they would most naturally be expected, viz.:—

Of *axial* organs: the *primary node* or transitional region between stem and root, and the *flowering axis*; of *foliar* organs: the *cotyledon*, the *sporophyll,* and the *integument* of the sporangium.

In the axial organs or stems of modern Cycads the vascular tissue consists of, in five genera, a single cylinder; in the four remaining genera, of *more than one or several cylinders.* These cylinders are *collateral* in structure.

In the region of the primary node, however, the structure of the one or more outer cylinders exhibits a variation in that it approximates to the *concentric* type, either by the appearance of an *inversely-orientated* zone attached to the *inner* face of each cylinder, or by the breaking up of the cylinder into a number of *concentric* or partially concentric independent strands.

The first of these two types of primary nodal structure is normally characteristic of *Medullosa porosa*, the second of *Medullosa Solmsii.*

In the peduncle of the male cone of *Stangeria* the single cylinder consists in its lower portion of bundles which, by their irregularly curved, sub-concentric, or sometimes *perfectly concentric* contour, betray their derivation from a cylinder of *concentric strands* like that of *Medullosa Solmsii.*

The primitive vascular bundle of the *foliar* organs from which that in all the various foliar organs of modern Cycads has been derived is, on the view here set forth, held to be the type exhibited by the leaf of *Lyginodendron* (Rachiopteris): it consists of a central mass of primary tracheides with several protoxylem-groups at the periphery, the whole being surrounded by phloem.

In the *foliage-leaves* of modern Cycads the concentric bundle becomes broken up into great numbers of collateral bundles, each with a conspicuous mass of centripetal primary tracheides. This very same character obtains in the foliage-leaves of all species of *Medullosa.*

In the *cotyledons, sporophylls,* and *sporangial integuments* of recent Cycads many of the bundles exhibit the primitive *concentric* type of structure, with the modification that in the cotyledon of *Stangeria,* the reduction in size of the bundle, in the sporophyll, as in *Encephalortos,* the development of the secondary centrifugal xylem has caused the disappearance of the central primary xylem; a modification which has also supervened in the case of the vascular strands of the stem. Hence the vascular structure of the *foliage-leaves* of the *Medulloseæ* is more advanced and modified than is that of the *cotyledons* and *sporophylls* of recent Cycads, and *à fortiori* than that of the foliage-leaf of *Lyginodendron.*

The central cylinder of the stem of *Lyginodendron Oldhamium* has the same origin as that of modern Cycads, as is shown (1) by the curved contour of the various strands composing it, betraying the origin of each from a *concentric* strand; and (2) by the occurrence of *inversely-orientated* vascular tissue on the *inner* side of the cylinder, abnormally in *L. Oldhamium* and *normally* in *L. robustum.*

The single stele of *Heterangium* is, homologous with each single *concentric* stele once, on this view, composing the cylinder of *Lyginodendron,* as with each such stele in *Medullosa Solmsii* and *M. anglica.*

Three stages of advancement are, therefore, to be noted in the vascular structure of this great phylum:—

The *Filices* possess a vascular system in essentials wholly *concentric*; in the *Cycado-filices* the *collateral* character first makes its appearance; in *Cycads* the *collateral* strongly predominates, while the *concentric* has almost died out.

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5. *On the Structure of the Stem of* Angiopteris evecta, *Hoffm.* *By* R. F. Shove, *Girton College, Cambridge.*

This paper deals with the anatomy of the stem and roots of a plant of *Angiopteris evecta* from Ceylon. The older part of the obliquely ascending axis exhibits a distinct dorsiventrality and gives off numerous roots from the lower surface; in the younger part of the stem the structure becomes more radial and the roots are much less abundant.

The mode of origin of the leaf-traces and their connection with the stelar framework in the stem, which has the form of a series of inverted funnel-shaped zones, is worked out in detail, the result in a few points differing somewhat from those obtained by Mettenius.

The steles of the stem are both mesarch and endarch in structure, but the protoxylem groups occupy for the most part a peripheral position. The earliest protoxylem appears along the inner edge of the steles, while the protophloem arises on the outer edge of each stele as a discontinuous arc of small and rather thick-walled elements. This arc of protophloem is never completed round the stele, but the next stage in the development of the tissues after the appearance of the protoxylem is the differentiation of large sieve-tubes external to the protophloem.

Air-roots and earth-roots were anatomically investigated, and the origin of the latter was traced from the vascular lattice-work of the stem. Several initial cells were recognised in the apical region of the stem.

MONDAY, SEPTEMBER 10.

1. A Joint Discussion with Section C was held on the Conditions under which the Plants of the Coal Period grew.—See p. 746.

The following Papers were read:—

2. *Further Investigations on the Intumescences of* Hibiscus vitifolius (*Linn.*). *By* ELIZABETH DALE.

The author previously examined the structure of certain intumescences (outgrowths) on the green parts of *Hibiscus vitifolius*, and made some preliminary experiments which pointed to the conclusion that the conditions determining the formation of outgrowths were moisture, warmth, and light.[1]

During the present summer (1900) the experiments have been extended. The effects of moist air and moist soil were tested, and plants were also grown under glass of various colours, in bright sunlight, in shade, and under whitewashed glass at different temperatures. The following results were obtained. In a moist *atmosphere*, bright sunlight, and a high temperature, large numbers of intumescences were formed in two or three days. The most striking results were obtained by isolating a single normal branch (still attached to the plant) in a bell-jar containing damp air, and exposed to direct sunlight, in very hot weather.

Outgrowths were also formed under red, yellow, and whitewashed glass, but not under blue or green glass, nor on plants grown in the open air. The distribution of the outgrowths is dependent upon that of the stomata, both in *Hibiscus* and also in other plants. There is no doubt that the checking of transpiration (which is very active in this plant) by a damp atmosphere is one cause of the development of outgrowths; but this by itself is not sufficient, as the experiments under blue and green glass show. It is necessary that assimilation also be active. There is further evidence (partly furnished by the plants grown under coloured glass) that an altered course of metabolism is also involved; a conclusion to which the abnormally abundant development of oil also points. It seems clear that what occurs is (1) a lack of salts owing to the arrested transpiration; (2) the assimilated carbohydrates are therefore being employed in metabolism with a deficiency of nitrates; and (3) the tissues blocked with water are not respiring normally. That the abnormal outgrowths and accumulation of oil are indications of the disturbed metabolism is not surprising.

The formation of outgrowths often begins round the teeth of the leaf. The structure of the bundle-endings in the teeth of a normal leaf is that which characterises water-glands; and this fact, taken in connection with the position and structure of the intumescences, suggests that they may be organs for the excretion of water.

3. *On the Osmotic Properties and their Causes in the Living Plant and Animal Cell. By* Professor E. F. OVERTON.

A very great number of experiments on the permeability of the living protoplasm of plant and animal cells has led to the conclusion that the general osmotic properties of the cell depend on a phenomenon of elective solubility, certain layers of protoplasm being impregnated with a mixture of lecithin and cholesterin. All substances that are soluble in this mixture, and they include by far the greater number of organic compounds, are able to penetrate into the living cell. The rapidity of the passage of different compounds into the cell depends on their rela-

[1] E. Dale, 'On certain Outgrowths (Intumescences) on the Green Parts of *Hibiscus vitifolius* (Linn.),' *Proc. Camb. Phil. Soc.* (1900), vol. x. Pt. IV. p. 192.

tive solubility in water and in a mixture of cholesterin and lecithin. A knowledge of the osmotic properties of the living protoplasm throws much light on the action of many poisons and other drugs.

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4. *The Biology and Cytology of a New Species of Pythium.* *By* Professor A. H. Trow.

1. The reproductive organs of this fungus, 'conidia' and oospores, were found in rotten cress seedlings in July 1899, and the species has been cultivated as a saprophyte on sterilised potatoes, house-flies, cabbage leaves, &c., up to the present time (September 1900).

2. The species appears to be a pure saprophyte, all attempts to infect fresh cress seedlings having hitherto failed.

3. Pure cultures were obtained by infecting sterilised potatoes with materials obtained from cultures on rhubarb leaves.

4. On potatoes an aërial mycelium is freely developed, which remains sterile for weeks. Conidia and oospores ultimately develop in numbers, their presence being readily recognised by their yellow colour.

5. On house-flies or bits of cabbage leaves immersed in water the mycelium is aquatic, and, as a rule, that developed on house-flies produces conidia, that on cabbage leaves oospores.

6. The life history has been carefully followed under the microscope in moist-chamber cultures. It is noteworthy—

(*a*) That De Bary erred in including the greater portion of the periplasm in the oosphere.

(*b*) That there is no sharp line of differentiation between periplasm and gonoplasm in the antheridium.

(*c*) That most of the periplasm is absorbed by the young oospore, which in consequence increases in size.

(*d*) That the conidia and oospores on germination invariably produce germ tubes, no zoospores being formed under any circumstances.

(*e*) That the conidia germinate at once in a decoction of cabbage leaves, but remain at rest in distilled water; that the oospores germinate at once, as soon as ripe, or after a rest of as much as seven months.

7. The species is consequently new and ranks as the most highly developed of the genus.

8. The mycelium 'conidia,' oogonia, and antheridia are multinucleate, the oosphere is uninucleate, the young oospore binucleate, and the ripe oospore uninucleate.

9. The nuclei multiply by indirect division in the mycelium and sexual organs. No nuclear changes of importance take place in the 'conidia.' The only nuclear fusion is that of the male and female nuclei in fertilisation. The number of chromosomes is considerable, certainly more than six.

10. The oogonium, as it is formed, receives fifteen or more nuclei, the antheridium three or more. These invariably divide once, so that the number of nuclei is doubled. The supernumerary nuclei in the oogonium lie in the periplasm, the female nucleus passes to and occupies the centre of the oosphere. No similar distribution of the nuclei takes place in the antheridium.

11. The fertilisation tube penetrates the wall of the oogonium at a spot prepared for it, passes through the periplasm, and penetrates deeply into the egg. One male nucleus passes down the tube and enters the egg. The oosphere clothes itself with a delicate cell-wall and increases in size.

12. The fusion of the male and female nuclei is delayed until a thick oospore wall has developed. No epispore is formed.

13. The fate of the nucleus in the germinating oospore has not yet been followed. In the conidia nuclear divisions occur as germination proceeds.

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5. *Observations on* Pythium. *By* G. POIRAULT *and* E. J. BUTLER.

The genus is of wide distribution, being found chiefly in the soil, but also in water. Seven species were examined, two being undescribed forms. Two others, *P. gracile*, Schenk, and *P. intermedium*, formed sexual organs hitherto unknown in these species. They are both parasites, the former in green algæ, the latter in the roots of a number of phanerogams, and are also both capable of saprophytic life. All forms are able to form sporanges and gonidia, some giving one sort of spore more readily than the other. Klebs's results on the dependence of spore-formation in *Saprolegnia* on external circumstances were carried a step further, it being shown that a given spore could be induced to give zoospores or vegetative hyphæ on appropriate treatment.

The process of zoospore-formation differs considerably from that described by previous authors, being closely comparable to that of the *Saprolegniaceæ*. A vacuole is formed in the discharging process, probably containing a cellulose-altering enzyme and some chemiotactic substance whose function it is to draw out the protoplasm from the sporange into the spore vesicle. The ripe sporange also contains a motile vacuole which discharges to the exterior just before the escape of the protoplasm. Septa are formed in all species. *Pythium* represents a stage in the colonisation of the land by saprolegniaceous ancestors resembling *Aphanomyces*. It is closely linked to the Peronosporaceæ through *P. intermedium*, which possesses chains of gonidia, suckers, and a thick-walled resting mycelium.

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6. *Observations on some* Chytridineæ. *By* G. POIRAULT *and* E. J. BUTLER.

Four undescribed forms occur parasitic on *Pythium*. Their life history has been worked out.

Chytridium gregarium, Nowakowski, was found on the eggs of the rotifer *Metopidia lepadella*. The unknown resting spores were discovered.

Two observations were made on *Olpidiopsis saprolegniæ*. The infection takes place in the zoospore stage of Saprolegnia, and is often multiple. Penetration takes place by a fine tube through which the protoplasm of the parasitic zoospore enters the host, leaving behind an empty capsule.

A sort of diplanetism occurs in Olpidiopsis, the zoospore shedding its two cilia, altering shape and acquiring two new cilia one after the other.

The work was carried out chiefly at the Villa Thuret, Antibes.

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7. *On the Azygospores of* Entomophthora glœospora. *By* Professor P. VUILLEMIN.

The genus *Entomophthora*, as seen in the two species *E. Delpiniana* and *E. glœospora*, shows an intermediate condition between *Basidiobolus*, with its uninucleated segments, and *Empusa*, with its continuous hyphæ with scattered nuclei; for in *Entomophthora* the nuclei are large, and arranged at regular intervals in a single row. This state of things had led me to regard the non-septate condition as arising from the failure to develop septa for the delimitation of the cytoplasmic areas of the individual nuclei resulting from the division of a parent nucleus, and to describe the condition as 'apocytial,' and the multinucleate mass of protoplasm so formed as an 'apocyte' or 'apocytium.' An examination of the resting-spores alone found in *Entomophthora* has revealed the following history of their formation. They may be terminal, lateral, or intercalary, and in the limbs of *Mycetophila* these spores may be found of all ages, and arranged in basipetal succession of age, as shown by the increasing thickening of the wall from $0{\cdot}75\mu$ to 4μ, or even $5{\cdot}6\mu$.

The youngest spores contain a single nucleus, which undergoes a series of four successive binary divisions until there are 16; however, there may be irregularities so that the number may fall as low as 12, and in one case I have counted as many as 17. In the next stage the nuclei approach so as to form eight pairs, and the two nuclei of each pair then fuse: this fusion is repeated until at length

there are only two left. These last two may then fuse at once, so as to leave the now maturing zygospore with a single nucleus, or they may remain apart. The last stages of maturation are accompanied by the appearance of oil drops in the cytoplasm, which fuse towards its centre into a single large drop, reducing the protoplasmic contents of the spore to a peripheral envelope, with one or two parietal nuclei, as the case may be.

I can only interpret this formation as a case of true apogamy, and attribute to the process a value corresponding with the sexual process of *Basidiobolus*, since they both have the same starting-point, the same intermediate stage of nuclear division, and the same final nuclear fusion.

8. *On the Life History of* Acrospeira mirabilis (*Berk. and Br.*). *By* R. H. Biffen.

Loose brown masses of the spores of this fungus are occasionally found in Spanish chestnuts. These spores are developed from the apices of hyphæ coiled into a spiral of, at the most, two turns, which becomes septate into three cells; the cell next below the apical one swells and becomes thick-walled, thus forming a chlamydospore. The coiled hypha may also develop into a spiral resembling the ascogonium of *Eurotium*, which, after investment by branches arising from its apex, breaks down into chlamydospores. In this way bodies very suggestive of the spore-masses of some of the ustilagineæ are formed. Endoconidia are found in old cultures. Some evidence has also been obtained for the existence of an ascigerous stage.

TUESDAY, SEPTEMBER 11.

The following Papers were read:—

1. *Embryonic Tissues. By* Professor Marshall Ward, *F.R.S.*

I would submit for discussion whether we could not improve our terminology and teaching regarding the nature and growth of the tissues termed embryonic. As is well known, Sachs and those whom he has influenced term all the tissues of the growing points, cambium, pericycle, &c., embryonic tissues; but I want to point out that this term in its simple form should be reserved for the embryo alone. Only while the embryo consists of a few cells can we regard these cells as embryonic tissues in the sense that all are nearly alike; at a later stage the tissues of the growing points of stem and root have been derived from this embryonic tissue, and in any case differ normally from it in that instead of being capable of developing all or any parts of the plant, they are more and more restricted to the power of developing only shoots, leaves, &c., or only roots. Still more limited is the power of the cambium: it is normally confined to developing new xylem and phloem—not even new organs—and similarly with other so-called embryonic tissues of subsequent derivation. In view of such facts, and of others which we can all supply, I would suggest that we restrict the term *embryonic tissue*, or *primary embryonic tissue*, to that of the embryo only, before the desmogen strands are laid down, and speak of all other tissues as *derived* or *secondary tissues*. Thus the derived tissues of the growing points—capable of initiating organs as well as tissues—might be termed *secondary embryonic tissue*, and the cambium, &c., restricted embryonic tissues.

The fact that such tissues retain sufficient of their primary properties to develop whole organs, shoots, roots, &c., under modified or abnormal conditions does not invalidate the distinctions referred to, and further classification and subdivisions along these lines could be made to meet the necessities of such cases as *desmogen* (capable of laying down proto-xylem, &c.) and *cambium* (capable of

forming secondary xylem and phloem only), which seem to me still too vaguely defined in our text-books.

Such a classification would also apply to lower organisms. Indeed, my attention was first drawn to the matter by the observation that some algæ and schizomycetes appear to be always in the embryonic stage.

This brings us to a second point. Attention is now always drawn to the differences between the slow dimensional growth of the so-called embryonic tissues of the growing points and the stretching phase which Sachs called to our notice. But it seems to me we ought to recognise that we have two fundamentally different things here. It is, I think, hopeless to restrict the meaning of the word 'growth' (as understood by botanists) only to that mode of dimensional increase by the intersusception of solid particles in the non-vacuolated protoplasm of the true embryonic tissue of an embryo, and which implies a real gain in substance by the assimilation—in the sense of the word employed by animal physiologists—of food-materials. Yet this is real growth. The word 'growth,' as understood by botanists, refers almost exclusively to the possibly totally different dimensional increase implied in the extension of cells under pressure of vacuoles, and, taking into account the respiratory activity which prevails, is attended by loss of substance.

I would therefore suggest that we should distinguish the *assimilatory growth* of true embryonic tissue from the *vacuolar growth* of the derived tissues. This can easily be done now that we are beginning to discard the misleading phrase 'carbon dioxide assimilation' in favour of some such term as 'photo-synthesis.'

Here, again, clearness is, I think, attained by the change in the consideration of those algæ and schizophytes in which no vacuoles can be detected. It would be absurd to say they do not grow; but it seems pretty clear that they grow by *assimilatory growth* and not by *vacuolar growth* or extension. At the same time we must not forget that invisible vacuoles may exist in the meshes of protoplasm, though even if this be so it is difficult to see how the protoplasm in the trabeculæ between grows if not by the intercalation of solid molecular units.

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2. *The Behaviour of the Nucleolus during Karyokinesis in the Root Apex of* Phaseolus. *By* Harold Wager.

From a study of the changes undergone by the nucleolus during karyokinesis in cells of the root apex of *Phaseolus multiflorus* the following chief results have been obtained.

1. The nucleolus is the most conspicuous object in the nucleus of the young meristematic cells. The nuclear network forms a delicate peripheral layer only in the resting nucleus.

2. The nucleolus stains deeply in hæmatoxylin, the nuclear network slightly; in safranin and gentian violet the nucleolus stains red, the nuclear network light blue; in gentian violet the nucleolus often shows a more deeply stained central portion.

3. In the resting condition of the nucleus the nucleolus is suspended to the delicate nuclear network by delicate filaments.

4. The nucleolus often shows a vacuolar structure, especially in the stage just previous to division.

5. In the process of nuclear division the nucleolus first of all becomes irregular in shape, and the nucleolar substance appears to pass, by means of the connecting strands, into the nuclear network, which thereby becomes more prominent.

6. As the chromosomes are formed the nucleolus disappears, but a portion of the nucleolus is often visible in the equatorial plate.

7. The chromatic substance of the chromosomes appears to be derived almost entirely from the nucleolus, but a part of the nucleolus may possibly be used up in the formation of the spindle fibres.

8. As the daughter nuclei are being formed the chromatic substance of the chromosomes runs together into small spheres, which ultimately fuse together to form the single large nucleolus.

3. *On the Presence of Seed-like Organs in certain Palæozoic Lycopods.* *By* D. H. Scott, *F.R.S.*

Specimens discovered by Messrs. Wild and Lomax in the Ganister beds of the Lower Coal-measures of Lancashire prove that the seed-like bodies described by Williamson under the name of *Cardiocarpon anomalum* were borne on strobili, agreeing completely in morphology and anatomy with *Lepidostrobus.*

Each megasporangium, which, as usual in Lepidodendreæ, was seated on the upper surface of the sporophyll, became enclosed, when mature, in an integument springing from the tissue of the sporophyll-pedicel. The integument closed in over the top of the sporangium, leaving only a narrow crevice or micropyle, which differed in its elongated, slit-like form from the more or less tubular micropyle of an ordinary seed.

Within the megasporangium four megaspores were produced, one of which occupied almost the whole of the sporangial cavity, while the other three remained small, and were evidently abortive.

The integumented megasporangium, containing the single functional megaspore or embryo-sac, became detached, together with the remains of its sporophyll, from the cone. It appears to have been indehiscent, and presents close analogies with a true seed.

In a specimen from Burntisland, practically identical with the Coal-measure form, though presumably of a different species, the prothallus was found fairly preserved. It formed a large-celled tissue, occupying the interior of the functional megaspore.

In a male strobilus, probably of the same species as the Coal-measure specimens above described, the microsporangia were found to be provided with integuments, resembling those of the megasporangia but more widely open.

It is proposed to give the generic name *Lepidocarpon* to the Lepidostroboid fructification now described.[1] Though its seed-like reproductive bodies were referred to *Cardiocarpon* by Williamson, they have no affinity with the Cordaitean seeds constituting the genus *Cardiocarpon* of Brongniart, to which the true *C. anomalum* of Carruthers belongs.

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4. *The Primary Structure of certain Palæozoic Stems referred to* Araucarioxylon. *By* D. H. Scott, *F.R.S.*

The chief object of the present communication is to exhibit some illustrations of facts already briefly recorded elsewhere.[2]

The genus *Araucarioxylon* is an artificial one, founded to include fossil specimens with secondary wood resembling that of a recent *Araucaria.* The Palæozoic forms of *Araucarioxylon* have been shown to belong in most cases to the stems of the extinct Gymnospermous order Cordaiteæ, which was in some respects intermediate between Cycadales and Coniferæ.

The Cordaitean stems hitherto investigated appear to have resembled Coniferæ in the development of their wood, for the spiral first-formed tracheides are found in contact with the pith, the whole of the wood, primary as well as secondary, having thus been developed in centrifugal order.

The specimens now illustrated are peculiar in possessing distinct strands of primary wood in the pith. They belong to two species, both from the Lower Carboniferous rocks of Scotland and the North of England.

In one, *Araucarioxylon fasciculare*, sp. nov., the pith is small, but the primary strands of xylem are of large size, attaining their maximum diameter when about to pass out towards a leaf. Their structure is mesarch, and they closely

[1] A somewhat fuller account of *Lepidocarpon* has been communicated to the Royal Society, and a complete illustrated description is in preparation.

[2] Scott, 'On the Primary Wood of certain Araucarioxylons,' *Annals of Botany*, December 1899.

resemble the corresponding strands in *Lyginodendron Oldhammium*. The secondary wood has narrow medullary rays, and quite resembles that of an araucarian Conifer.

The other species is identical with the *Araucarioxylon antiquum* described by Witham. Here the pith is of large size, nearly an inch in diameter in the specimen illustrated, and is surrounded by a ring of forty or fifty small primary xylem bundles, mesarch in structure, which appear to have passed out into the leaves in pairs. In this form the secondary wood has somewhat broad medullary rays, and is so far less Coniferous in character than that of *A. fasciculare*.

The interest of the two species described consists in their affording a link, so far as the primary structure of the wood is concerned, between certain of the Cycadofilices and the Cordaiteæ.

The author is indebted to Mr. R. Kidston, F.G.S., for the loan of the specimens on which the investigation is based.

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5. *On the Structure and Affinities of* Dipteris conjugata, *Reinw., with Notes on the Geological History of the Dipteridinæ. By* A. C. Seward, *F.R.S., and* Elizabeth Dale.

For the material used in the anatomical investigation of *Dipteris conjugata* the authors are indebted to Mr. Shelford, of the Sarawak Museum, Borneo, and to Mr. Yapp, of Caius College, Cambridge. The genus *Dipteris* is represented by four recent species: *D. conjugata*, Reinw. [= *Polypodium* (*Dipteris*) *Horsfieldii*, R. Br.], *D. Wallichii*, R. Br., *D. Lobbiana*, Hk., and *D. quinquefurcata*, Baker; of these *D. Wallichii* occurs in the subtropical regions of Northern India, the other three species being characteristic of the Malayan region. Among Mesozoic ferns the genera *Protorhipis, Dictyophyllum, Camptopteris* afford examples of extinct types closely allied to *Dipteris*, and widely spread geographically during the Jurassic epoch.

The authors propose to separate the recent genus and the fossil forms from the Polypodiaceæ and place them in a distinct family—the Dipteridinæ. The sporangial characters of *Dipteris* do not conform precisely to those typical of the Polypodiaceæ, and the anatomical features afford additional evidence in favour of placing *Dipteris* in a special subdivision of the Leptosporangiate ferns.

The stem of *Dipteris conjugata* possesses a single annular stele in which the protoxylem strands occupy a central (mesarch) position. The protophloem elements are sharply marked off from the rest of the phloem, which is succeeded by a pericycle 3–4 cells in width; a distinct endodermis encloses the stele both internally and externally. Immediately behind each leaf the annular stele of the stem becomes elongated in a vertical direction, and gives off an inverted U-shaped branch which ascends obliquely upwards into the leaf-stalk. The foliar gap, left after the passing off of the meristele, closes up in front of the leaf, and the stele resumes its normal tubular form.

The paper deals also with the structure of the roots, leaves, and sporangia of *Dipteris conjugata*, the comparison of the anatomical features with those of the Cyatheaceæ and other ferns, and concludes with an account of the geological and geographical range of such fossil ferns as may reasonably be placed in the family Dipteridinæ.

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6. *Illustrations of Sand-binding Plants. By* Professor F. O. Bower, *F.R.S.*

INDEX.

References to reports and papers printed in extenso *are given in Italics.*
*An Asterisk * indicates that the title only of the communication is given.*
The mark † indicates the same, but a reference is given to the Journal or Newspaper where the paper is published in extenso.

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1885. ‡Aberdeen, The Countess of. Haddo House, Aberdeen.
1885. ‡*Abernethy, David W. Ferryhill Cottage, Aberdeen.*
1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S Rathmore Lodge, Bolton-gardens South, Earl's Court, S.W.

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1884. ‡Acheson, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1900. §Ackroyd, William, Borough Laboratory, Crossley Street, Halifax.
1882. *Acland, Alfred Dyke. 38 Pont-street, Chelsea, S.W.
1869. ‡Acland, Sir C. T. Dyke, Bart., M.A. Killerton, Exeter.
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1877. *Acland, Theodore Dyke, M.A. 74 Brook-street, W.
1898. ‡Acworth, W. M. 47 St. George's-square, S.W.
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1884. *Archibald, E. Douglas. Constitutional Club, Northumberland Avenue, W.C.
1883. §Armistead, Richard. Chambres House, Southport.
18 *Armistead, William. Hillcrest, Oaken, Wolverhampton.
1883. ‡Armitage, Benjamin. Chomlea, Pendleton, Manchester.
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1873. *ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S., Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 55 Granville Park, Lewisham, S.E.

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1889. ‡*Armstrong, John A. 32 Eldon-street, Newcastle-upon-Tyne.*

1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.

1893. ‡Arnold-Bemrose, H., M.A., F.G.S. 56 Friar-gate, Derby.

1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.

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1890. ‡Ashworth, J. Reginald, B.Sc. 105 Freehold-street, Rochdale.

1887. ‡Ashworth, John Wallwork, F.G.S. Thorne Bank, Heaton Moor, Stockport.

1887. ‡Ashworth, Mrs. J. W. Thorne Bank, Heaton Moor, Stockport.

1887. ‡Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.

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1861. ‡*Aston, Theodore. 11 New-square, Lincoln's Inn, W.C.*

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1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.

1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.

1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.

1883. ‡Baildon, Dr. 65 Manchester-road, Southport.

1892. ‡Baildon, H. Bellyse. Duncliffe, Murrayfield, Edinburgh.

Year of Election.

1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1893. §BAILEY, Colonel F., Sec. R.Scot.G.S., F.R.G.S. 7 Drummond-place, Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Marple Cottage, Marple, Cheshire.
1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1899. §§Bailey, T. Lewis. 35 Hawarden-avenue, Liverpool.
1855. ‡Bailey, W. Horseley Fields Chemical Works, Wolverhampton.
1887. ‡*Bailey, W. H. Summerfield, Eccles Old-road, Manchester.*
1894. *Baily, Francis Gibson, M.A. 11 Ramsay-garden, Edinburgh.
1878. ‡BAILY, WALTER. 4 Roslyn-hill, Hampstead, N.W.
1885. ‡BAIN, ALEXANDER, M.A., LL.D. Ferryhill Lodge, Aberdeen.
1897. §BAIN, JAMES, jun. Toronto.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *BAKER, Sir BENJAMIN, K.C.M.G., LL.D., D.Sc., F.R.S., M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1898. ‡Baker, Herbert M. Wallcroft, Durdham Park, Clifton, Bristol.
1898. ‡Baker, Hiatt C. Mary-le-Port-street, Bristol.
1891. ‡Baker, J. W. 50 Stacey-road, Cardiff.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1875. ‡BAKER, W. PROCTOR. Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, The Right Hon. G. W., M.P. 24 Addison-road, Kensington, W.
1894. §Balfour, Henry, M.A. 11 Norham-gardens, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S., Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D., Regius Professor of Surgery in the University of Dublin. 24 Merrion-square, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. ‡Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. ‡Bamford, Professor Harry, B.Sc. McGill University, Montreal, Canada.
1899. §Bampton, Mrs. 42 Marine-parade, Dover.
1882. ‡Bance, Colonel Edward, J.P. Oak Mount, Highfield, Southampton.
1898. §§Bannerman, W. Bruce, F.R.G.S., F.G.S. The Lindens, Sydenham-road, Croydon.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1894. §§Barclay, Arthur. 29 Gloucester-road, South Kensington, S.W.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.

Year of Election.

1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. ‡Barker, Alfred, M.A., B.Sc. Aske's Hatcham School, New Cross, S.E.
1899. §Barker, John H. 26 Park-parade, Cambridge.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Priddy Vicarage, Wells, Somerset.
1898. §Barker, W. R. 106 Redland-road, Bristol.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. Deene, Tooting Bec-road, Streatham, S.W.
1889. §Barlow, H. W. L., M.A., M.B., F.C.S. Holly Bank, Croftsbank-road, Urmston, near Manchester.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
1885. *Barlow, William, F.G.S. The Red House, Great Stanmore.
1873. ‡Barlow, William Henry, F.R.S., M.Inst.C.E. High Combe, Old Charlton, Kent.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1889. ‡Barnes, J. W. Bank, Durham.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1899. §§Barnes, Robert. 9 Kildare Gardens, Bayswater, W.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1899. §§Barnett, W. D. 41 Threadneedle-street, E.C.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1891. §Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1872. *Barrett, W. F., F.R.S., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Abbotsgate, Huyton, near Liverpool.
1899. §Barrett-Hamilton, Capt. G. E. H. Kilmarnock, Arthurstown, Waterford, Ireland.
1887. ‡Barrington, Miss Amy. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1893. *Barrow, George, F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.
1896. §Barrowman, James. Staneacre, Hamilton, N.B.
1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.

Year of Election.

1858. ‡BARRY, Right Rev. ALFRED, D.D., D.C.L. The Cloisters, Windsor.
1883. ‡Barry, Charles E. 1 Victoria-street, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances A. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond, M.Inst.C.E. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, G. C. T., M.P. St. Margaret's House, Victoria-street, S.W.
1892. ‡Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1893. ‡Barton, Edwin H., B.Sc. University College, Nottingham.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1899. *Barton, Miss Ethel S. 7 Brechin Place, South Kensington, S.W.
1892. ‡Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1898. ‡Bason, Vernon Millward. 7 Princess-buildings, Clifton, Bristol.
1876. ‡Bassano, Alexander. 12 Montagu-place, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1888. *BASSET, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, N.
1889. ‡BASTABLE, Professor C. F., M.A., F.S.S. 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Professor of the Principles and Practice of Medicine in University College, London. 8A Manchester-square, W.
1889. ‡Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡BATEMAN, Sir A. E., K.C.M.G., Controller General, Statistical Department. Board of Trade, 7 Whitehall Gardens, S.W.
1868. ‡Bateman, Sir F., M.D., LL.D. Upper St. Giles's-street, Norwich.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1884. ‡BATESON, WILLIAM, M.A., F.R.S. St. John's College, Cambridge.
1881. *BATHER, FRANCIS ARTHUR, M.A., D.Sc., F.G.S. British Museum (Natural History), S.W.
1863. §BAUERMAN, H., F.G.S. 14 Cavendish-road, Balham, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. §Bayly, F. W. 8 Royal Mint, E.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *BAYNES, ROBERT E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1883. *Bazley, Gardner S. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Winterdyne, Chine Crescent-road, Bournemouth.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.B., F.R.S. 61 Grosvenor-street, W.
1882. §Beamish, Lieut.-Colonel A. W., R.E. 27 Philbeach-gardens, S.W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.

Year of Election.

1883. ‡Beard, Mrs. Oxford.
1889. §BEARE, Prof. T. HUDSON, B.Sc., F.R.S.E., M.Inst.C.E. University College, W.C., and Park House, King's Road, Richmond.
1842. *Beatson, William. 2 Ash Mount, Rotherham.
1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, W.
1886. ‡Beaugrand, M. H. Montreal.
1900. §Beaumont, Prof. Roberts, M.I.Mech.E. Yorkshire College, Leeds.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. The Laboratory, Citadel Hill, Plymouth.
1885. *BEAUMONT, W. W., M.Inst.C.E., F.G.S. Outer Temple, 222 Strand, W.C.
1896. ‡Beazer, C. Hindley, near Wigan.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hall, Buxton, Derbyshire.
1885. ‡BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. §BEDDOE, JOHN, M.D., F.R.S. The Chantry, Bradford-on-Avon.
1896. §Bedford, F. P. 326 Camden Road, N.
1858. §Bedford, James. Woodhouse Cliff, near Leeds.
1890. ‡Bedford, James E., F.G.S. Shireoak-road, Leeds.
1891. §Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S., Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1891. *Belinfante, L. L., M.Sc., Assist.-Sec. G.S. Burlington House, W.
1892. ‡Bell, A. Beatson. 143 Princes-street, Edinburgh.
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. 35 Cambridge-street, Hyde Park, W.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1900. *Bell, H. Wilkinson. Holmehurst, Rawdon, near Leeds.
1862. *BELL, Sir ISAAC LOWTHIAN, Bart., LL.D., F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.
1875. ‡BELL, JAMES, C.B., D.Sc., Ph.D., F.R.S. Howell Hill Lodge, Ewell, Surrey.
1896. ‡Bell, James. Care of the Liverpool Steam Tug Co., Limited, Chapel-chambers, 28 Chapel-street, Liverpool.
1891. ‡*Bell, James. Bangor Villa, Clive-road, Cardiff.*
1871. *BELL, J. CARTER, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. 100 Leyland-road, Southport.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1893. ‡BELPER, The Right Hon. Lord, LL.M. Kingston, Nottinghamshire.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. The Grange, Knutsford.
1885. ‡BENHAM, WILLIAM BLAXLAND, D.Sc., Professor of Biology in the University of Otago, New Zealand.
1891. ‡Bennett, Alfred Rosling. 44 Manor Park-road, Harlesden, N.W.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, N.W.

Year of Election.

1896. §Bennett, George W. West Ridge, Oxton, Cheshire.
1881. §Bennett, John Ryan. 3 Upper Belgrave-road, Clifton, Bristol.
1883. *Bennett, Laurence Henry. The Elms, Paignton, South Devon.
1896. ‡Bennett, Richard. 19 Brunswick-street, Liverpool.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Stellenbosch, South Africa.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1897. ‡Bently, R. R. 97 Dowling-avenue, Toronto, Canada.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1894. §Berkeley, The Right Hon. the Earl of. Foxcombe, Boarshill, near Abingdon.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1898. §Berridge, Miss C. E. Wellscot, Hayward's Lane, Cheltenham.
1894. §Berridge, Douglas, M.A., F.C.S. The College, Malvern.
1862. ‡BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1882. *Bessemer, Henry. Town Hill Park, West End, Southampton.
1890. ‡Best, William Woodham. 31 Lyddon-terrace, Leeds.
1880. *BEVAN, Rev. JAMES OLIVER, M.A., F.G.S. 55 Gunterstone-road, W.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1870. ‡Bickerton, A. W. Newland Terrace, Queen's Road, Battersea, S.W.
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1885. *BIDWELL, SHELFORD, Sc.D., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, S.E.
1898. §Billington, Charles. Studleigh, Longport, Staffordshire.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, Lieut.-Colonel John E., J.P. West Lea, Ranmoor, Sheffield.
1881. ‡BINNIE, Sir ALEXANDER R., M.Inst.C.E., F.G.S. London County Council, Spring-gardens, S.W.
1873. ‡Binns, J. Arthur. 31 Manor Row, Manningham, Bradford, Yorkshire.
1899. §Bird, F. J. Norton House, Midsomer Norton, Bath.
1880. ‡Bird, Henry, F.C.S. South Down House, Millbrook, near Devonport.
1888. *Birley, Miss Caroline. 14 Brunswick-gardens, Kensington, W.
1887. *Birley, H. K. Hospital, Chorley, Lancashire.
1871. *BISCHOF, GUSTAV. 19 Ladbroke-gardens, W.
1894. ‡Bisset, James. 5 East India-avenue, E.C.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Major W. H. Engineer's Office, Cincinnati, Ohio, U.S.A.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1889. ‡*Black, William. 12 Romulus-terrace, Gateshead.*
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡*Blackall, Thomas. 13 Southernhay, Exeter.*
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.

Year of Election.

1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
1900. §Blackburn, W. Owen. 3 Mount Royd, Bradford.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 1 Belhaven-terrace, Kelvinside, Glasgow.
1896. §Blackie, Walter W., B.Sc. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1896. ‡Blackwood, J. M. 16 Oil-street, Liverpool.
1886. ‡Blaikie, John, F.L.S. The Bridge House, Newcastle, Staffordshire.
1895. ‡Blaikie, W. B. 6 Belgrave-crescent, Edinburgh.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1883. *BLAKE, Rev. J. F., M.A., F.G.S. 69 Comeragh-road, W.
1846. *Blake, William. Bridge, South Petherton, Somerset.
1891. ‡BLAKESLEY, THOMAS H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, S.E.
1894. ‡Blakiston, Rev. C. D. Exwick Vicarage, Exeter.
1900. *Blamires, Joseph. Bradley Lodge, Huddersfield.
1881. ‡Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1895. ‡Blamires, William. Oak House, Taylor Hill, Huddersfield.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡BLANFORD, W. T., LL.D., F.R.S., F.G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, W.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J., B.Sc. Newnham Lea, Grange-road, Cambridge.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1880. ‡*Bloxam, G. W., M.A.* 11 *Presburg Street, Clapton, N.E.*
1888. §Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. Hazelwood, Crumpsall Green, Manchester.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby.
1859. ‡*Blunt, Captain Richard. Bretlands, Chertsey, Surrey.*
Blyth, B. Hall. 135 George-street, Edinburgh.
1885. ‡BLYTH, JAMES, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1870. ‡Boardman, Edward. Oak House, Eaton, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1900. §BODINGTON, Principal N., M.A. Yorkshire College, Leeds.
1889. ‡Bodmer, G. R., Assoc.M.Inst.C.E. 30 Walbrook, E.C.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1898. §Bolton, H. The Museum, Queen's-road, Bristol.
1876. ‡Bolton, J. C. Carbrook, Stirling.
1894. §Bolton, John. 15 Clifton-road, Crouch End, N.
1898. ‡Bolton, J. W. Baldwin-street, Bristol.
1898. §BONAR, J., M.A., LL.D. 1 Redington-road, Hampstead, N.W.
1883. ‡Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1871. *BONNEY, Rev. THOMAS GEORGE, D.Sc., LL.D., F.R.S., F.S.A., F.G.S. 23 Denning-road, Hampstead, N.W.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.

Year of Election.

1890. *BOOTH, CHARLES, D.Sc., F.R.S., F.S.S. 24 Great Cumberland Place, W.
1883. ‡Booth, James. Hazelhurst, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, W.C.
1876. ‡Booth, Rev. William H. Mount Nod-road, Streatham, S.W.
1883. ‡Boothroyd, Benjamin. Solihull, Birmingham.
1900. §Borchgrevinck, C. E. Douglas Lodge, Bromley, Kent.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 19 Alexandra-road, Wimbledon, Surrey.
1876. *BOSANQUET, R. H. M., M.A., F.R.S., F.R.A.S. Castillo Zamora, Realejo-Alto, Tenerife.
1896. ‡Bose, Dr. J. C. Calcutta, India.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §BOTHAMLEY, CHARLES H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Otterwood, Beaconsfield-road, Weston-super-Mare.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. 4 Godwyne-road, Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. ‡Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.
1871. *BOTTOMLEY, JAMES THOMSON, M.A., D.Sc., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. ‡Bottomley, W. B., B.A., Professor of Botany, King's College, W.C.
1876. ‡Bottomley, William, jun. 15 University-gardens, Glasgow.
1890. ‡Boulnois, Henry Percy, M.Inst.C.E. 44 Campden House Court, Kensington, W.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, S.W.
1883. ‡BOURNE, A. G., D.Sc., F.R.S., F.L.S., Professor of Biology in the Presidency College, Madras.
1893. *BOURNE, G. C., M.A., F.L.S. Savile House, Mansfield-road, Oxford.
1889. ‡*Bourne, R. H. Fox.* 41 *Priory-road, Bedford Park, Chiswick.*
1866. §BOURNE, STEPHEN. 5 Lansdown-road, Lee, S.E.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.
1898. §§Bovey, Edward P., jun. Clifton Grove, Torquay.
1884. ‡BOVEY, HENRY T., M.A., M.Inst.C.E., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1881. *BOWER, F. O., D.Sc., F.R.S., F.R.S.E., F.L.S., Regius Professor of Botany in the University of Glasgow.
1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Royal Societies Club, St. James's-street, S.W.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1898. §Bowley, A. L., M.A. Waldeck House, Southern Hill, Reading.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E. Mayfield, Knutsford, Cheshire.
1899. *Bowman, Herbert Lister, M.A. 13 Sheffield-gardens, Kensington, W.
1899. *Bowman, John Herbert. 13 Sheffield Gardens, Kensington, W.
1887. §Box, Alfred Marshall. Care of Cooper, Box & Co., 69 Aldermanbury, E.C.
1895. *BOYCE, RUBERT, M.B., Professor of Pathology, University College, Liverpool.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.

Year of Election.

1865. ‡BOYLE, The Very Rev. G. D., M.A. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1892. §BOYS, CHARLES VERNON, F.R.S. 27 The Grove, Boltons, S.W.
1872. *BRABROOK, E. W., C.B., F.S.A. 178 Bedford-hill, Balham, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1894. *Braby, Ivon. Bushey Lodge, Teddington, Middlesex.
1893. §Bradley, F. L. Bel Air, Alderley Edge, Cheshire.
1899. *Bradley, J. W., Assoc.M.Inst.C.E. Town Hall, Wolverhampton.
1892. §Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, S.O., Essex.
1864. ‡*Braham, Philip.* 3 *Cobden-mansions, Stockwell-road, S.E.*
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1898. §Bramble, James R. Seafield, Weston-super-Mare.
1865. §BRAMWELL, Sir FREDERICK J., Bart., D.C.L., LL.D., F.R.S., M.Inst.C.E. 5 Great George-street, S.W.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. 72 Hills Road, Cambridge.
1885. *Bratby, William, J.P. Alton Lodge, Hale, Bowdon, Cheshire.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, W.C.
1877. ‡*Brent, Francis.* 19 *Clarendon-place, Plymouth.*
1898. §Brereton, Cuthbert A., M.Inst.C.E. 21 Delahay-street, S.W.
1882. *Bretherton, C. E. 26 Old Broad Street, E.C.
1866. ‡Brettell, Thomas. Dudley.
1891. ‡Brice, Arthur Montefiore, F.G.S., F.R.G.S. 159 Strand, W.C.
1886. §§BRIDGE, T. W., M.A., D.Sc., Professor of Zoology in the Mason University College, Birmingham.
1870. *Bridson, Joseph R. Bryerswood, Windermere.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN, M.P. Kildwick Hall, Keighley, Yorkshire.
1890. ‡Brigg, W. A. Kildwick Hall, Keighley, Yorkshire.
1893. ‡Bright, Joseph. Western-terrace, The Park, Nottingham.
1868. ‡Brine, Admiral Lindesay, F.R.G.S. United Service Club, Pall Mall, S.W.
1893. ‡Briscoe, Albert E., B.Sc., A.R.C.Sc. Municipal Technical Institute, Romford-road, West Ham, E.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1898. ‡BRISTOL, the Right Rev. G. F. BROWNE, Lord Bishop of, D.D. 17 The Avenue, Clifton, Bristol.
1879. *BRITTAIN, W. H., J.P., F.R.G.S. Storth Oaks, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. 9 Vanbrugh-hill, Blackheath, S.E.
1899. §§Broadwood, Miss Bertha M. Pleystowe, Capel, Surrey.
1899. §§Broadwood, James H. E. Pleystowe, Capel, Surrey.
1897. ‡Brock, W. R. Toronto.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1883. *Brodie, David, M.D. Care of Bernard Holländer, 61 Chancery-lane, W.C.

Year of Election.

1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. 5 Devonshire-place, Eastbourne.
1881. ‡Brook, Robert G. Wolverhampton House, St. Helens, Lancashire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1883. *Brotherton, E. A. Arthington Hall, Wharfedale, viâ Leeds.
1883. *Brough, Mrs. Charles S. Rosendale Hall, West Dulwich, S.E.
1886. ‡Brough, Professor Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwith.
1885. *Browett, Alfred. 29 Wheeley's-road, Birmingham.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., V.P.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1892. ‡Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew, near Glasgow.
1896. ‡Brown, A. T. The Nunnery, St. Michael's Hamlet, Liverpool.
1867. ‡Brown, Sir Charles Gage, M.D., K.C.M.G. 88 Sloane-street, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1883. *Brown, Mrs. H. Bienz. Fochabers, Morayshire.
1883. ‡Brown, Mrs. Helen. Canaan-grove, Newbattle-terrace, Edinburgh.
1870. §Brown, Horace T., LL.D., F.R.S., F.G.S. 52 Nevern-square, S.W.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. Canaan-grove, Newbattle-terrace, Edinburgh.
1895. ‡Brown, J. Allen, J.P., F.R.G.S., F.G.S. 7 Kent-gardens, Ealing, W.
1870. *Brown, Professor J. Campbell, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Longhurst, Dunmurry, Belfast.
1881. *Brown, John, M.D. Stockbridge House, Padisham, Lancashire.
1882. *Brown, John. 7 Second-avenue, Nottingham.
1895. *Brown, John Charles. 2 Baker-street, Nottingham.
1894. ‡Brown, J. H. 6 Cambridge-road, Brighton.
1882. *Brown, Mrs. Mary. Stockbridge House, Padisham, Lancashire.
1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.
1897. ‡Brown, Price, M.B. 37 Carlton-street, Toronto, Canada.
1886. §Brown, R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1897. ‡Brown, Richard. Jarvis-street, Toronto, Canada.
1896. ‡Brown, Stewart H. Quarry Bank, Allerton, Liverpool.
1891. §Brown, T. Forster, M.Inst.C.E., F.G.S. Guild Hall Chambers, Cardiff.
1865. ‡*Brown, William. 41A New-street, Birmingham.*
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.

Year of Election.

1900. §Browne, Frank Balfour. Goldielea, Dumfries, Scotland.
1892. ‡*Browne, Harold Crichton. Crindon, Dumfries.*
1895. *Browne, H. T. Doughty. 10 Hyde Park-terrace, W.
1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, S.W.
1891. ‡BROWNE, MONTAGU, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1887. ‡*Brownell, T. W. 6 St. James's-square, Manchester.*
1865. ‡Browning, John, F.R.A.S. 63 Strand, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡*Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.*
1892. ‡Bruce, James. 10 Hill-street, Edinburgh.
1893. ‡Bruce, William S. 11 Mount Pleasant, Joppa, Edinburgh.
1900. *Brumm, Charles. Lismara, Grosvenor Road, Birkdale, Southport.
1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1863. ‡Brunel, I. 15 Devonshire-terrace, W.
1875. ‡Brunlees, John, M.Inst.C.E. 12 Victoria-street, Westminster, S.W.
1896. *Brunner, Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
1868. ‡BRUNTON, Sir T. LAUDER, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1878. §§Brutton, Joseph. Yeovil.
1886. *BRYAN, G. H., D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. ‡BRYCE, Rev. Professor GEORGE. Winnipeg, Canada.
1897. ‡BRYCE, Right Hon. JAMES, D.C.L., M.P., F.R.S. 54 Portland-place, W.
1894. ‡Brydone, R. M. Petworth, Sussex.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S., F.R.S.E., Sec. Scottish Meteorological Society. 42 Heriot-row, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. 10 Moray-place, Edinburgh.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡Buckland, Miss A. W. 5 Beaumont-crescent, West Kensington, W.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1865. **Buckley, Henry.* 18 *Princes-street, Cavendish-square, W.*
1886. §§Buckley, Samuel. Merlewood, Beaver Park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Penryn, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1893. §BULLEID, ARTHUR, F.S.A. Glastonbury.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, S.W.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1895. ‡Bunte, Dr. Hans. Karlsruhe, Baden.
1886. §BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, W.

Year of
Election.

1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1894. ‡BURKE, JOHN, B. B. Trinity College, Cambridge.
1884. *Burland, Lieut.-Col. Jeffrey H. 824 Sherbrook-street, Montreal, Canada.
1899. §Burls, Herbert T. 206 Lewisham High-road, S.E.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, G.C.I.E., K.C.S.I., F.R.G.S. 132 Sutherland-gardens, Maida Vale, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. 11 Belmont-street, Aberdeen.
1877. ‡Burns, David. Alston, Carlisle.
1884. ‡Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1899. §§Burr, Malcolm. Dorman's Park, East Grinstead.
1887. ‡Burroughs, Eggleston, M.D. Snow Hill-buildings, E.C.
1883. *Burrows, Abraham. Russell House, Rhyl, North Wales.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1894. ‡Burstall, H. F. W. 76 King's-road, Camden-road, N.W.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, W.
1894. ‡Burton, Charles V. 24 Wimpole-street, W.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Little Aston, Sutton Coldfield.
1897. ‡Burton, S. H., M.B. 50 St. Giles's-street, Norwich.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. 11 Union Crescent, Margate.
1897. ‡Burwash, Rev. N., LL.D., Principal of Victoria University, Toronto, Canada.
1887. *Bury, Henry. Trinity College, Cambridge.
1899. §Bush, Anthony. 43 Portland-road, Nottingham.
1895. §Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1884. *Butterworth, W. Park Avenue, Temperley, near Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1883. ‡*Buxton, Miss F. M. Newnham College, Cambridge.*
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1881. ‡Buxton, Sydney. 15 Eaton-place, S.W.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. ‡Buxton, Sir Thomas Fowell, Bart., G.C.M.G., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. 22 Dingle-lane, Toxteth Park, Liverpool.
1899. §Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. ‡Byrom, John R. Mere Bank, Fairfield, near Manchester.

1889. ‡Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1892. ‡Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1894. ‡Caillard, Miss E. M. Wingfield House, near Trowbridge, Wilts.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.

Year of Election.

1861. *Caird, James Key. 8 Roseangle, Dundee.
1886. **Caldwell, William Hay. Cambridge.*
1868. ‡Caley, A. J. Norwich.
1887. ‡CALLAWAY, CHARLES, M.A., D.Sc., F.G.S. 35 Huskisson-street, Liverpool.
1897. §CALLENDAR, Prof. HUGH L., M.A., F.R.S. University College, Gower Street, W.C., and 2 Chester Place, Regent's Park, N.W.
1892. ‡Calvert, A. F., F.R.G.S. Royston, Eton-avenue, N.W.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡*Cameron, Sir Charles, Bart., M.D., LL.D. 1 Huntly-gardens, Glasgow.*
1857. ‡CAMERON, Sir CHARLES A., C.B., M.D. 15 Pembroke-road, Dublin
1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1876. ‡Campbell, Right Hon. James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1897. ‡Campbell, Major J. C. L. New Club, Edinburgh.
1898. §§Campbell, Mrs. Napier. 81 Ashley-gardens, S.W.
1897. ‡Campion, B. W. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡CANNAN, EDWIN, M.A., F.S.S. 1 Wellington Square, Oxford.
1897. §Cannon, Herbert. Woodbank, Erith, Kent.
1898. ‡CANTERBURY, Right Hon. and Most Rev. F. TEMPLE, Lord Archbishop of. Lambeth Palace, S.E.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 27 Kensington Court-gardens, London, W.
1894. §CAPPER, D. S., M.A., Professor of Mechanical Engineering in King's College, W.C.
1883. ‡Capper, Mrs. R. 9 Bridge-street, Westminster, S.W.
1887. ‡Capstick, John Walton. University College, Dundee.
1873. *CARBUTT, Sir EDWARD HAMER, Bart., M.Inst.C.E. 19 Hyde Park-gardens, W.
1896. *Carden, H. V. Balinveney, Bookham, Surrey.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1898. ‡Carlile, George M. 7 Upper Belgrave-road, Bristol.
1867. ‡Carmichael, David (Engineer). Dundee.
1897. ‡Carmichael, Norman R. Queen's University, Kingston, Ontario, Canada.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.
1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1897. ‡Carpenter, R. C. Cornell University, Ithaca, New York, U.S.A.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1893. ‡CARR, J. WESLEY, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. 14 Vermont-road, Norwood, S.E.
1886. ‡CARSLAKE, J. BARHAM. 30 Westfield-road, Birmingham.
1899. §Carslaw, H. S., D.Sc. The University, Glasgow.
1883. ‡Carson, John. 51 Royal-avenue, Belfast.
1868. *Carteighe, Michael, F.C.S., F.I.C. 180 New Bond-street, W.

Year of
Election.

1897.§§Carter, E. Tremlett. 'The Electrician,' Salisbury Court, Fleet Street, E.C.
1866. ‡Carter, H. H. The Park, Nottingham.
1870. ‡Carter, Dr. William. 78 Rodney Street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1900. *Carter, Rev. W. Lower, F.G.S. Hopton, Mirfield.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1896. §Cartwright, Miss Edith G. 21 York Street Chambers, Bryanston Square, W.
1878. *Cartwright, Ernest H., M.A., M.D. Bower Terrace, Maidstone.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I., Borough and Water Engineer. Albion-place, Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Argyll-terrace, Derby.
1894. ‡Carus, Paul. La Salle, Illinois, U.S.A.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, S.W.
1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1897. *Case, Willard E. Auburn, New York, U.S.A.
1896. *Casey, James. 10 Philpot-lane, E.C.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1900. *Cassie, W., M.A. Professor of Physics in the Royal Holloway College, Brantwood, Englefield Green.
1897. ‡Caston, Harry Edmonds Featherston. 340 Brunswick-avenue, Toronto, Canada.
1888. ‡*Cater, R. B. Avondale, Henrietta Park, Bath.*
1874. ‡Caton, Richard, M.D. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyles, Mrs. Isabella. Lancaster House, 102 Palace-road, Tulse Hill, S.W.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John, New Brunswick, Canada.
1883. ‡Chambers, Mrs. Bombay.
1881. *Champney, John E. 27 Hans Place, S.W.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, Sir James T., Bart. 1 Grand-avenue, Brighton.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1861. *Chapman, Edward, M.A., M.P., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1897. ‡Chapman, Edward Henry. 17 St. Hilda's-terrace, Whitby.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1900. §Chapman, L. J. 79 St. Bees Street, Moss Lane East, Manchester.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1899. §Chapman, Sydney John. University College, Cardiff.
1877. ‡Chapman, T. Algernon, M.D. 17 Wesley-avenue, Liscard, Cheshire.
1874. ‡Charles, J. J., M.D., Professor of Anatomy and Physiology in Queen's College, Cork. Newmarket, Co. Cork.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡*Charnock, Richard Stephen, Ph.D., F.S.A. Crichton Club, Adelphi-terrace, W.C.*

Year of Election.

1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1884. *Chatterton, George, M.A., M.Inst.C.E. 6 The Sanctuary, Westminster, S.W.
1886. *Chattock, A. P., M.A., Professor of Experimental Physics in University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
1884. ‡Chauveau, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡Cheadle, W. B., M.A., M.D., F.R.G.S. 19 Portman-street, Portman-square, W.
1900. §Cheesman, W. Norwood. The Crescent, Selby.
1887. ‡Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1896. ‡Chenie, John. Charlotte-street, Edinburgh.
1874. *Chermside, Major-General Sir H. C., R.E., G.C.M.G., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1896. ‡Cherry, R. B. 92 Stephen's Green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
1883. ‡Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1889. ‡Chirney, J. W. Morpeth.
1894. ‡Chisholm, G. G., M.A., B.Sc., F.R.G.S. 59 Drakefield Road, Upper Tooting, S.W.
1899. §Chitty, Edward. Suffolk House, London-road, Dover.
1899. §Chitty, Mrs. Edward. Suffolk House, London-road, Dover.
1899. §Chitty, G. W. Mildura, Park-avenue, Dover.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1893. *Chree, Charles, D.Sc., F.R.S., Superintendent of the Kew Observatory, Richmond, Surrey.
1900. *Christie, R. J. Duke Street, Toronto, Canada.
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. May Villa, Lucien-road, Tooting Common, S.W.
1876. *Chrystal, George, M.A., LL.D., F.R.S.E., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §Church, A. H., M.A., F.R.S., F.S.A., Professor of Chemistry in the Royal Academy of Arts. Shelsley, Ennerdale-road, Kew.
1898. §Church, Colonel G. Earl, F.R.G.S. 216 Cromwell-road, S.W.
1860. ‡Church, Sir William Selby, Bart., M.D. St. Bartholomew's Hospital, E.C.
1896. §Clague, Daniel, F.G.S. 5 Sandstone-road, Stoneycroft, Liverpool.
1890. ‡Clark, E. K. 13 Wellclose-place, Leeds.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
Clark, George T. 44 Berkeley-square, W.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1892. ‡*Clark, James, M.A., Ph.D., Professor of Agriculture in the Yorkshire College, Leeds.*
1892. ‡Clark, James. Chapel House, Paisley.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc. 112 Wool Exchange, E.C.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1887. §Clarke, C. Goddard, J.P. Fairlawn, 157 Peckham-rye, S.E.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.

Year of Election.

1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1886. ‡Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1875. ‡CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1897. §Clarke, Colonel S. C., R.E. Parklands, Caversham, near Reading.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1896. §Clarke, W. W. Albert Dock Office, Liverpool.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1889. §CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
1866. ‡Clayden, P. W. 13 Tavistock-square, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1859. ‡Cleghorn, John. Wick.
1875. ‡*Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.*
1861. §CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1898. ‡Clissold, H. 30 College-road, Clifton, Bristol.
1893. ‡Clofford, William. 36 Mansfield-road, Nottingham.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 38 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. ‡Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *CLOWES, FRANK, D.Sc., F.C.S. London County Council, Spring-gardens, S.W., and 17 Bedford Court-mansions, W.C.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1885. ‡Clyne, James. Rubislaw Den South, Aberdeen.
1891. *Coates, Henry. Pitcullen House, Perth.
1897. ‡Coates, J., M.Inst.C.E. 99 Queen-street, Melbourne, Australia.
1884. §Cobb, John. Westfield, Ilkley, Yorkshire.
1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. ‡Cockburn, John. Glencorse House, Milton Bridge, Edinburgh.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1898. §§Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, S.W.
1896. *Coghill, Percy de G. 4 Sunnyside, Prince's Park, Liverpool.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1894. *Colby, Miss E. L., B.A. Carregwen, Aberystwyth.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby William Henry. Carregwen, Aberystwyth.
1803. ‡Cole, Prof. Grenville A. J., F.G.S. Royal College of Science, Dublin.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1864. ‡Colefax, H. Arthur, Ph.D., F.C.S. 14 Chester-terrace, Chester-square, S.W.
1897. §COLEMAN, Dr. A. P. 476 Huron-street, Toronto, Canada.
1893. ‡Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1899. §Coleman, William. The Shrubbery, Buckland, Dover.
1878. ‡Coles, John. 1 Savile-row, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.

Year of Election.

1899. §Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1892. ‡Collie, Alexander. Harlaw House, Inverurie.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 16 Campden-grove, W.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1893. ‡Collinge, Walter E. Mason College, Birmingham.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 69 Great Russell-street, W.C.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1876. ‡COLLINS, J. H., F.G.S. 162 Barry-road, S.E.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 17 Victoria-street, S.W.
1884. ‡Colomb, Sir J. C. R., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, S.W.
1897. ‡Colquhoun, A. H. U., B.A. 39 Borden-street, Toronto, Canada.
1896. *Comber, Thomas, F.L.S. Leighton, Parkgate, Chester.
1888. ‡Commans, R. D. Macaulay-buildings, Bath.
1884. ‡COMMON, A. A., LL.D., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, W.
1891. ‡Common, J. F. F. 21 Park-place, Cardiff.
1900. §Common, T. A., B.A. 63 Eaton Rise, Ealing, W.
1892. ‡Comyns, Frank, M.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1896. ‡Connacher, W. S. Birkenhead Institute, Birkenhead.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C. 4 Queen's Elms, Belfast.
1893. ‡CONWAY, Sir W. M., M.A., F.R.G.S. The Red House, Hornton-street, W.
1899. §COODE, J. CHARLES, M.Inst.C.E. Westminster-chambers, 9 Victoria-street, S.W.
1898. §Cook, Ernest H. 27 Berkeley-square, Clifton, Bristol.
1900. §Cook, Walter. 98 St. Mary's Street, Cardiff.
1882. ‡COOKE, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, S.W.
1876. *COOKE, CONRAD W. 28 Victoria-street, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1895. ‡*Cooke, Miss Janette E. Holmwood, Thorpe, Norwich.*
1868. ‡COOKE, M. C., M.A. 53 Castle Road, Kentish Town, N.W.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishopshill, York.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1896. ‡Cookson, E. H. Kiln Hey, West Derby.
1888. ‡*Cooley, George Parkin. Cavendish Hill, Sherwood, Nottingham.*
1899. *Coomara Swamy, A. K. Walden, Worplesdon, Guildford.
1895. ‡Cooper, Charles Friend, M.I.E.E. 68 Victoria-street, Westminster, S.W.
1893. ‡Cooper, F. W. 14 Hamilton-road, Sherwood Rise, Nottingham.
1883. ‡*Cooper, George B. 67 Great Russell-street, W.C.*
1868. ‡Cooper, W. J. New Malden, Surrey.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. †COPELAND, RALPH, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.

Year of Election.

1885. ‡*Copland, W., M.A. Tortorston, Peterhead, N.B.*
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1891. ‡Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. Fairlight, Oliver Grove, South Norwood, S.E.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
1883. *Core, Professor Thomas H., M.A. Fallowfield, Manchester.
1870. *CORFIELD, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiene and Public Health in University College, London. 19 Savile-row, W.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. ‡Cornish, Vaughan, M.Sc., F.R.G.S. Branksome Cliff, Branksome Park, Bournemouth.
1884. *Cornwallis, F. S. W., M.P., F.L.S. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Park Hill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 57 Park Hill-road, Croydon.
1900. §Cortie, Rev. A. L., F.R.A.S. Stonyhurst College, Blackburn.
1891. ‡Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, W.C.
1891. *Cotsworth, Haldane Gwilt. The Cedars, Cobham Road, Norbiton, S.W.
1874. *COTTERILL, J. H., M.A., F.R.S. 15 St. Alban's-mansions, Kensington Court-gardens, W.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, S.W.
1869. ‡*COTTON, WILLIAM. Pennsylvania, Exeter.*
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1889. ‡*Courtney, F. S. 77 Redcliffe-square, South Kensington, S.W.*
1896. ‡COURTNEY, Right Hon. LEONARD. 15 Cheyne Walk, Chelsea, S.W.
1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
1896. ‡Coventry, J. 19 Sweeting-street, Liverpool.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.L.S., F.G.S. 17 King William-street, Strand, W.C.
1900. §Cowburn, Henry. Dingle Head, Westleigh, Leigh, Lancashire.
1895. *COWELL, PHILIP H., M.A. Royal Observatory, Greenwich, S.E.
1871. ‡*Cowper, C. E. 6 Great George-street, Westminster, S.W.*
1899. §Cowper-Coles, Sherard. 82 Victoria-street, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1867. *Cox, George Addison. Beechwood, Dundee.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. ‡Crabtree, William. 126 Manchester-road, Southport.
1890. ‡Cradock, George. Wakefield.
1892. *Craig, George A. 66 Edge-lane, Liverpool.
1884. §CRAIGIE, Major P. G., F.S.S. 6 Lyndhurst-road, Hampstead, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.

Year of
Election.

1887. ‡Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey.
1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. Dun Echt, Aberdeen.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Craiglockhart, Edinburgh.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, N.
1870. *Crawshay, Mrs. Robert. Caversham Park, Reading.
1885. §CREAK, Captain E. W., R.N., F.R.S. 9 Hervey-road, Blackheath, S.E.
1896. ‡Cregeen, A. C. 21 Prince's-avenue, Liverpool.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1896. §Crichton, Hugh. 6 Rockfield-road, Anfield, Liverpool.
1880. *Crisp, Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. Clouneagh, Ballingarry-Lacy, co. Limerick.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡*Crombie, Charles W. 41 Carden-place, Aberdeen.*
1885. ‡CROMBIE, J. W., M.A., M.P. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. §CROOK, HENRY T. 9 Albert-square, Manchester.
1898. §Crooke, William. Langton House, Charlton Kings, Cheltenham.
1865. §CROOKES, Sir WILLIAM, F.R.S., V.P.C.S. 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *CROOKSHANK, E. M., M.B., Professor of Bacteriology in King's College, London, W.C.
1870. ‡Crosfield, C. J. Gledhill, Sefton Park, Liverpool.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *CROSFIELD, WILLIAM. Annesley, Aigburth, Liverpool.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1887. §§Cross, John. Beaucliffe, Alderley Edge, Cheshire.
1861. ‡*Cross, Rev. John Edward, M.A., F.G.S. Halecote, Grange-over-Sands.*
1853. ‡Crosskill, William. Beverley, Yorkshire.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1897. *Crosweller, Mrs. W. T. Kent Lodge, Sidcup, Kent.
1894. ‡*Crow, C. F. Home Lea, Woodstock Road, Oxford.*
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry, M.D. 116 Manningham Lane, Bradford.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-upon-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.
1898. ‡CRUNDALL, Sir WILLIAM H. Dover.
1888. ‡Culley, Robert. Bank of Ireland, Dublin.
1883. *CULVERWELL, EDWARD P., M.A. 40 Trinity College, Dublin.

Year of
Election.

1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1897. ‡Cumberland, Barlow. Toronto, Canada.
1898. §Cundall, J. Tudor. 1 Dean Park-crescent, Edinburgh.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *Cunningham, Lieut.-Colonel Allan, R.E., A.I.C.E. 20 Essex-villas, Kensington, W.
1877. *Cunningham, D. J., M.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in Trinity College, Dublin.
1891. ‡Cunningham, J. H. 4 Magdala-crescent, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1885. ‡Cunningham, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡Cunningham, Robert O., M.D., F.L.S., F.G.S., Professor of Natural History in Queen's College, Belfast.
1883. *Cunningham, Rev. W., D.D., D.Sc. Trinity College, Cambridge.
1892. §Cunningham-Craig, E. H., B.A., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1900. *Cunnington, W. Alfred. 13 The Chase, Clapham Common, S.W.
1892. *Currie, James, jun., M.A., F.R.S.E. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1898. ‡Curtis, John. 1 Christchurch-road, Clifton, Bristol.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, S.W.

1889. ‡Dagger, John H., F.I.C. Victoria Villa, Lorne-street, Fairfield, Liverpool.
1854. ‡Daglish, Robert. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1898. §Dalby, Prof. W. E. 6 Coleridge-road, Crouch End, N.
1889. *Dale, Miss Elizabeth. 2 Trumpington Street, Cambridge.
1863. ‡Dale, J. B. South Shields.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H., D.D., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡Danby, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1876. §Dansken, John, F.R.A.S. 2 Hillside Gardens, Partickhill, Glasgow.
1896. §Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1894. ‡Darbishire, B. V., M.A., F.R.G.S. 1 Savile-row, W.
1897. ‡Darbishire, C. W. Elm Lodge, Elm-row, Hampstead, N.W.
1897. §§Darbishire, F. V., Ph.D. Hopefield, Denison Road, Victoria Park, Manchester.
1861. *Darbishire, Robert Dukinfield, B.A. 26 George-street, Manchester.
1896. ‡Darbishire, W. A. Penybryn, Carnarvon, North Wales.
1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.
1882. ‡Darwin, Francis, M.A., M.B., F.R.S., F.L.S. Wychfield, Huntingdon-road, Cambridge.

Year of Election.

1881. *DARWIN, GEORGE HOWARD, M.A., LL.D., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *DARWIN, HORACE. The Orchard, Huntingdon-road, Cambridge.
1894. *DARWIN, Major LEONARD, Hon. Sec. R.G.S. 12 Egerton-place, South Kensington, S.W.
1882. ‡Darwin, W. E., M.A., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 11 St. James's-square, Bath.
1872. ‡Davenport, John T. 64 Marine-parade, Brighton.
1880. *DAVEY, HENRY, M.Inst.C.E., F.G.S. 3 Prince's-street, Westminster, S.W.
1898. §Davey, William John. 6 Water-street, Liverpool.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1891. ‡Davies, Andrew, M.D. Cefn Parc, Newport, Monmouthshire.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1893. *Davies, Rev. T. Witton, B.A., Ph.D. Baptist College, Bangor.
1898. §Davies, Wm. Howell, J.P. Down House, Stoke Bishop, Bristol.
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 37 Ladbroke Grove, W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1896. *Davis, John Henry Grant. Balcombe Road, Hayward's Heath, Sussex.
1885. *Davis, Rev. Rudolf. Hopefield, Evesham.
1891. ‡*Davis, W. 48 Richmond-road, Cardiff.*
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡DAVISON, CHARLES, D.Sc. 16 Manor-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, E. W., M.D. Kimmage Lodge, Roundtown, Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T. The Lilacs, Prestatyn, North Wales.
1864. ‡DAWKINS, W. BOYD, D.Sc., F.R.S., F.S.A., F.G.S., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1897. §§DAWSON, G. M., C.M.G., LL.D., F.R.S., Director of the Geological Survey of Canada. Ottawa, Canada.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington, Burnsall, Skipton.
1884. ‡Dawson, Samuel. 258 University-street, Montreal, Canada.
1859. *Dawson, Captain William G. The Links, Plumstead Common, Kent.
1892. ‡Day, T. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *DEACON, G. F., M.Inst.C.E. 19 Warwick-square, S.W.
1900. §Deacon, M. Whittington House, near Chesterfield.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. 4 Schlangenweg, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1893. ‡Deeley, R. M. 38 Charnwood-street, Derby.

Year of Election.

1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1884. *De Laune, C. De L. F. Sharsted Court, Sittingbourne.
1870. ‡*De Meschin, Thomas, B.A., LL.D. 2 Dr. Johnson's Buildings, Temple, E.C.*
1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1897. §Denison, F. Napier. Meteorological Office, Victoria, B.C., Canada.
1896. ‡Denison, Miss Louisa E. 16 Chesham-place, S.W.
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in University College, Sheffield.
Dent, William Yerbury. 5 Caithness-road, Brook Green, W.
1874. ‡DE RANCE, CHARLES E., F.G.S. 33 Carshalton Road, Blackpool.
1896. ‡DERBY, The Right Hon. the Earl of, G.C.B. Knowsley, Prescot, Lancashire.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, W.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1899. ‡DEVONSHIRE, The Duke of, K.G., D.C.L., F.R.S. 78 Piccadilly, W.
1899.§§Dewar, A. Redcote. Redcote, Leven, Fife.
1868. ‡DEWAR, JAMES, M.A., LL.D., F.R.S., F.R.S.E., V.P.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William, M.A. Horton House, Rugby.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, W.
1887. ‡DE WINTON, Major-General Sir F., G.C.M.G., C.B., D.C.L., LL.D., F.R.G.S. United Service Club, Pall Mall, S.W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *DEW-SMITH, A. G., M.A. Chesterton Hall, Cambridge.
1896. ‡D'Hemry, P. 136 Prince's-road, Liverpool.
1897. ‡Dick, D. B. Toronto, Canada.
1889. ‡Dickinson, A. H. The Wood, Maybury, Surrey.
1863. ‡Dickinson, G. T. Lily-avenue, Jesmond, Newcastle-upon-Tyne.
1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund, M.A., F.G.S. 2 Starkie-street, Preston.
1887. §DICKSON, H. N., B.Sc., F.R.S.E., F.R.G.S. 2 St. Margaret's-road, Oxford.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡*Dickson, T. A. West Cliff, Preston.*
1862. *DILKE, The Right Hon. Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1900. §DIVERS, Dr. EDWARD, F.R.S. 9 Rugby Mansions, Kensington, W.
1898. *Dix, John William S. Hampton Lodge, Durdham Park, Clifton, Bristol.
1899 *DIXON, A. C., D.Sc., Professor of Mathematics in Queen's College, Galway.
1874. *DIXON, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Mentone Villa, Sunday's Well, Cork.
1900. §Dixon, A. Francis, D.Sc., Professor of Anatomy in University College, Cardiff.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.

Year of Election.

1888. §Dixon, Edward T. Messrs. Lloyds, Barnetts, & Bosanquets' Bank, 54 St. James's-street, S.W.
1900. *Dixon, George, M.A. St. Bees, Cumberland.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1896. §Dixon-Nuttall, F. R. Ingleholme, Ecclestone Park, Prescot.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1890. ‡Dobbie, James J., D.Sc. University College, Bangor, North Wales.
1885. §Dobbin, Leonard, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. Hartley Manor, Longfield, Kent.
1897. ‡Doberck, William. The Observatory, Hong Kong.
1892. ‡Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. ‡Dobson, G. Alkali and Ammonia Works, Cardiff.
1893. ‡Dobson, W. E., J.P. Lenton-road, The Park, Nottingham.
1875. *Docwra, George. 19 Clarence Street, Gloucester.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1897. ‡Dodge, Richard E. Teachers' College, Columbia University, New York, U.S.A.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1898. ‡Dole, James. Redland House, Bristol.
1893. ‡Donald, Charles W. Kinsgarth, Braid-road, Edinburgh.
1885. ‡Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *DONKIN, BRYAN, M.Inst.C.E. The Mount, Wray Park, Reigate.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1896. ‡Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1861. ‡Donnelly, Major-General Sir J. F. D., R.E., K.C.B. 59 Onslow-gardens, S.W.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Illawara House, Tunbridge Wells.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1884. *Dowling, D. J. Bromley, Kent.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. 91 Cheyne-walk, S.W.
1887. ‡Doxey, R. A. Slade House, Levenshulme, Manchester.
1894. ‡Doyne, R. W., F.R.C.S. 28 Beaumont-street, Oxford.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. 188 Nethersdale Drive, Pollokshields, Glasgow.
1868. ‡DRESSER, HENRY E., F.Z.S. 110 Cannon-street, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.
1892. ‡Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. 118 High-street, Oxford.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1897. ‡Drynan, Miss. Northwold, Queen's Park, Toronto, Canada.
1892. ‡Du Bois, Dr. H. Mittelstrasse, 39, Berlin.

Year of Election.

1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, W.; and Tortworth Court, Falfield, Gloucestershire.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1900. *Duckworth, W. L. H. Jesus College, Cambridge.
1895. *Duddell, William. 47 Hans-place, S.W.
1867. *DUFF, The Right Hon. Sir MOUNTSTUART ELPHINSTONE GRANT-, G.C.S.I., F.R.S., F.R.G.S. 11 Chelsea-embankment, S.W.
1852. ‡DUFFERIN AND AVA, The Most Hon. the Marquis of, K.P., G.C.B., G.C.M.G., G.C.S.I., D.C.L., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, W.
1883. ‡Duke, Frederic. Conservative Club, Hastings.
1892. ‡Dulier, Colonel E., C.B. 27 Sloane-gardens, S.W.
1866. *Duncan, James. 9 Mincing-lane, E.C.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1880. ‡*Duncan, William S. 143 Queen's-road, Bayswater, W.*
1896. ‡Duncanson, Thomas. 16 Deane-road, Liverpool.
1881. ‡Duncombe, The Hon. Cecil, F.G.S. Nawton Grange, York.
1893. *Dunell, George Robert. 7 Spencer-road, Grove Park, Chiswick, Middlesex.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, E.C.
1896. *DUNKERLEY, S., M.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. ‡Dunn, J. T., M.Sc., F.C.S. Northern Polytechnic Institute Holloway-road, N.
1883. ‡Dunn, Mrs. Northern Polytechnic Institute, Holloway-road, N.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §Dunnington, Prof. F. P. University of Virginia, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1893. *Dunstan, M. J. R. Newcastle-circus, Nottingham.
1891. ‡Dunstan, Mrs. Newcastle-circus, Nottingham.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Director of the Scientific Department of the Imperial Institute, S.W.
1869. ‡D'Urban, W. S. M., F.L.S. Newport House, near Exeter.
1898. §§Durrant, R. G. Marlborough College, Wilts.
1895. *Dwerryhouse, Arthur R. 5 Oakfield-terrace, Headingley, Leeds.
1887. ‡*Dyason, John Sanford. Cuthbert Street, W.*
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Bletchley.
1895. §Dymond, Thos. S., F.C.S. County Technical Laboratory, Chelmsford.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1895. ‡Earle, Hardman A. 29 Queen Anne's-gate, Westminster, S.W.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.

Year of
Election.

1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1899. §East, W. H. Municipal School of Art, Science, and Technology, Dover.
1871. *EASTON, EDWARD. 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1893. *Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1870. *Eddison, John Edwin, M.D., M.R.C.S. The Lodge, Adel, Leeds.
1899. ‡Eddowes, Alfred, M.D. 28 Wimpole-street, W.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J., F.G.S. Silchar, Cachar, India.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. The College House, Leamington.
1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S., Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1884. *Edmunds, James, M.D. 26 Manchester-square, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B., F.G.S. 1 Garden-court, Temple, E.C.
1867. *Edward, Allan. Farington Hall, Dundee.
1899. §Edwards, E. J. 33 Newland-terrace, Queen's-road, Battersea, S.W.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1896. ‡Ekkert, Miss Dorothea. 95 Upper Parliament-street, Liverpool.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 113 Cannon-street, E.C.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1891. ‡Elliott, A. C., D.Sc., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1886. ‡ELLIOT, THOMAS HENRY, C.B., F.S.S. Board of Agriculture, 4 Whitehall-place, S.W.
1898. ‡*Elliott, W. J. 14 Buckingham Place, Clifton, Bristol.*
1877. ‡*Ellis, Arthur Devonshire. Thurnscoe Hall, Rotherham, Yorkshire.*
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1880. *ELLIS, JOHN HENRY. Woodhaye, Ivy Bridge, Devon.
1891. §Ellis, Miss M. A. 11 Canterbury-road, Oxford.
1884. ‡Ellis, Professor W. Hodgson, M.A., M.B. 74 St. Alban's-street, Toronto, Canada.
1869. ‡*Ellis, William Horton. Hartwell House, Exeter.*
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, Sir H. W., Bart., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, W.C.
1899. *Elvery, Miss Amelia. The Cedars, Maison Dieu-road, Dover.
1897. §Elvery, Mrs. Elizabeth. The Cedars, Maison Dieu-road, Dover.
1883. ‡Elwes, Captain George Robert. Bossington, Bournemouth.

Year of Election.

1887. §ELWORTHY, FREDERICK T. Foxdown, Wellington, Somerset.
1870. *ELY, The Right Rev. Lord ALWYNE COMPTON, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1897.§§Ely, Robert E. 744 Massachusetts-avenue, Cambridge, Massachusetts, U.S.A.
1891. ‡Emerton, Wolseley, D.C.L. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1890. ‡*Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.*
1894. ‡Emtage, W. T. A. University College, Nottingham.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, E. Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Enys, Penryn, Cornwall.
1894. ‡Erskine-Murray, James. Callander, Scotland.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles. 8 St. James's-square, John Dalton-street, Manchester.
1887. *Estcourt, Charles. Hayesleigh, Montague-road, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. Seymour House, Seymour Street, Manchester.
1869. ‡ETHERIDGE, R., F.R.S., F.R.S.E., F.G.S. 14 Carlyle-square, S.W.
1888. ‡Etheridge, Mrs. 14 Carlyle-square, S.W.
1883. ‡Eunson, Henry J., F.G.S., Assoc.M.Inst.C.E. Vizianagram, Madras.
1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.
1889. *EVANS, A. H., M.A. 9 Harvey-road, Cambridge.
1887. *Evans, Mrs. Alfred W. A. Lyndhurst, Upper Chorlton-road, Whalley Range, Manchester.
1870. *EVANS, ARTHUR JOHN, M.A., F.S.A. Youlbury, Abingdon.
1865. *EVANS, Rev. CHARLES, M.A. 41 Lancaster-gate, W.
1896.§§Evans, Edward, jun. Spital Old Hall, Bromborough, Cheshire.
1891. ‡Evans, Franklen. Llwynarthen, Castleton, Cardiff.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1883. *Evans, James C. 175 Lord-street, Southport.
1883. *Evans, Mrs. James C. 175 Lord-street, Southport.
1861. *EVANS, Sir JOHN, K.C.B., D.C.L., LL.D., D.Sc., F.R.S., F.S.A., F.L.S., F.G.S. Nash Mills, Hemel Hempstead.
1897. *Evans, Lady. Nash Mills, Hemel Hempstead.
1898. ‡Evans, Jonathan L. 4 Litfield-place, Clifton, Bristol.
1881. ‡Evans, Lewis. Llanfyrnach, R.S.O., Pembrokeshire.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. 15 Waterloo-crescent, Dover.
1899.§§Evans, Mrs. 15 Waterloo-crescent, Dover.
1875. ‡*Evans, Sparke. 3 Apsley-road, Clifton, Bristol.*
1865. *Evans, William. The Spring, Kenilworth.
1891. ‡*Evans, William Llewellin. Guildhall-chambers, Cardiff.*
1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. ‡Eve, H. Weston, M.A. 37 Gordon Square, W.C.
1868. *EVERETT, J. D., M.A., D.C.L., F.R.S., F.R.S.E. 11 Leopold Road, Ealing, W.
1895. ‡Everett, W. H., B.A. University College, Nottingham.

Year of Election.

1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1886. ‡Everitt, William E. Finstall Park, Bromsgrove.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡EWART, J. COSSAR, M.D., F.R.S., Professor of Natural History in the University of Edinburgh.
1874. ‡EWART, Sir W. QUARTUS, Bart. Glenmachan, Belfast.
1876. *EWING, JAMES ALFRED, M.A., B.Sc., F.R.S., F.R.S.E., M.Inst. C.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. Langdale Lodge, Cambridge.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1884. *Eyerman, John, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1890. ‡FABER, EDMUND BECKETT. Straylea, Harrogate.
1896. §Fairbrother, Thomas. 46 Lethbridge-road, Southport.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1886. ‡*Fairley, William. Beau Desert, Rugeley, Staffordshire.*
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Liverpool.
1883. ‡*Fallon, Rev. W. S. 9 St. James's-square, Cheltenham.*
1898. §Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
1877. §FARADAY, F. J., F.L.S., F.S.S. College-chambers, 17 Brazenose-street, Manchester.
1891. ‡*Fards, G. Penarth.*
1892. *FARMER, J. BRETLAND, M.A., F.R.S., F.L.S., Professor of Botany, Royal College of Science, Exhibition-road, S.W.
1886. ‡Farncombe, Joseph, J.P. Saltwood, Spencer-road, Eastbourne.
1897. *Farnworth, Ernest. Rosslyn, Goldthorn Hill, Wolverhampton.
1897. *Farnworth, Mrs. Ernest. Rosslyn, Goldthorn Hill, Wolverhampton.
1883. ‡Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1886. ‡FARQUHARSON, Colonel Sir J., K.C.B., R.E. Corrachee, Tarland, Aberdeen.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.
1885. *Farquharson, Mrs. R. F. O. Haughton, Aberdeen.
1866. *FARRAR, The Very Rev. FREDERIC WILLIAM, D.D., F.R.S. The Deanery, Canterbury.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1897. ‡Farthing, Rev. J. C., M.A. The Rectory, Woodstock, Ontario, Canada.
1869. *Faulding, Joseph. Boxley House, Tenterden, Kent.
1883. ‡Faulding, Mrs. Boxley House, Tenterden, Kent.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol.
1900. §FAWCETT, J. E., J.P. Low Royd, Apperley Bridge, Bradford.
1886.§§Felkin, Robert W., M.D., F.R.G.S. 6 Crouch Hall-road, N.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1900. *Fennell, W. John. Kilcoroon, Stockman's Lane, Belfast.
1883. †Fenwick, E. H. 29 Harley-street, W.
1890. ‡Fenwick, T. Chapel Allerton, Leeds.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.

Year of Election.

1896. *Ferguson, John. Colombo, Ceylon.
1867. ‡Ferguson, Robert M., LL.D., Ph.D., F.R.S.E. 5 Learmouth-terrace, Edinburgh.
1883. ‡Fernald, H. P. Clarence House, Promenade, Cheltenham.
1883. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, D.D., F.R.S. Caius College Lodge, Cambridge.
1873. ‡FERRIER, DAVID, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, W.
1892. ‡Ferrier, Robert M., B.Sc. College of Science, Newcastle-upon-Tyne.
1897. ‡Ferrier, W. F. Geological Survey, Ottawa, Canada.
1897. §§Fessenden, Reginald A., Professor of Electrical Engineering, University, Alleghany, Pennsylvania, U.S.A.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. Grammar School, Southampton.
1887. ‡Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1897. §§Field, George Wilton, Ph.D. Experimental Station, Kingston, Rhode Island, U.S.A.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
1878. *Findlater, Sir William. 22 Fitzwilliam-square, Dublin.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡Finnemore, Rev. J., M.A., Ph.D., F.G.S. 88 Upper Hanover-street, Sheffield.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
1895. §Fish, Frederick J. Spursholt, Park-road, Ipswich.
1891. ‡Fisher, Major H. O. The Highlands, Llandough, near Cardiff.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. 25 Blenheim-gardens, Willesden Green, N.W.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *FISON, FREDERICK W., M.A., M.P., F.C.S. Greenholme, Burley-in-Wharfedale, near Leeds.
1871. ‡FITCH, Sir J. G., M.A., LL.D. Athenæum Club, S.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §FITZGERALD, GEORGE FRANCIS, M.A., D.Sc., F.R.S., Professor of Natural and Experimental Philosophy in Trinity College, Dublin.
1885. *FitzGerald, Professor Maurice, B.A. 32 Eglantine-avenue, Belfast.
1894. †Fitzmaurice, M., M.Inst.C.E. Nile Reservoir, Assuan, Egypt.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
1888. *FITZPATRICK, Rev. THOMAS C. Christ's College, Cambridge.
1897. ‡Flavelle, J. W. 565 Jarvis-street, Toronto, Canada.
1881. ‡Fleming, Rev. Canon J., B.D. St. Michael's Vicarage, Ebury-square, S.W.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, Glasgow.
1876. ‡Fleming, Sir Sandford, K.C.M.G., F.G.S. Ottawa, Canada.
1867. ‡FLETCHER, ALFRED E., F.C.S. Delmore, Caterham, Surrey.
1870. ‡Fletcher, B. Edgington. Norwich.
1890. ‡Fletcher, B. Morley. 7 Victoria-street, S.W.
1892. ‡Fletcher, George, F.G.S. 60 Connaught-avenue, Plymouth.

Year of Election.

1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S., Keeper of Minerals, British Museum (Natural History), Cromwell-road, S.W. 36 Woodville-road, Ealing, W.

1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.

1877. *Floyer, Ernest A. Green Hill, Worcester.

1890. *FLUX, A. W., M.A., Professor of Political Economy in the Owens College, Manchester.

1887. ‡*Foale, William. 3 Meadfoot Terrace, Mannamead, Plymouth.*

1883. ‡*Foale, Mrs. William. 3 Meadfoot Terrace, Mannamead, Plymouth.*

1891. ‡Foldvary, William. Museum Ring, 10, Buda Pesth.

1880. ‡Foote, R. Bruce, F.G.S. Care of Messrs. H. S. King & Co., 65 Cornhill, E.C.

1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, S.W.

1883. ‡FORBES, HENRY O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.

1897. ‡Forbes, J., Q.C. Hazeldean, Putney-hill, S.W.

1885. ‡Forbes, The Right Hon. Lord. CastleForbes, Aberdeenshire.

1890. ‡FORD, J. RAWLINSON. Quarry Dene, Weetwood-lane, Leeds.

1875. *FORDHAM, H. GEORGE. Odsey, Ashwell, Baldock, Herts.

1894. ‡Forrest, Frederick. Beechwood, Castle Hill, Hastings.

1887. ‡FORREST, The Right Hon. Sir JOHN, G.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.

1883. ‡FORSYTH, A. R., M.A., D.Sc., F.R.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.

1900. §Forsyth, D. Central Higher Grade School, Leeds.

1884. ‡Fort, George H. Lakefield, Ontario, Canada.

1877. ‡FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.

1882. ‡*Forward, Henry. 10 Marine-avenue, Southend.*

1896. ‡FORWOOD, Sir WILLIAM B., J.P. Ramleh, Blundellsands, Liverpool.

1875. ‡Foster, A. Le Neve. 51 Cadogan-square, S.W.

1865. ‡Foster, Sir B. Walter, M.D., M.P. 16 Temple-row, Birmingham.

1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.R.S., F.G.S., Professor of Mining in the Royal College of Science, London. Llandudno.

1883. ‡Foster, Mrs. C. Le Neve. Llandudno.

1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., V.P.C.S. (GENERAL TREASURER.) Ladywalk, Rickmansworth.

1896. ‡Foster, Miss Harriet. Cambridge Training College, Wollaston-road, Cambridge.

1877. §Foster, Joseph B. 4 Cambridge-street, Plymouth.

1859. *FOSTER, Sir MICHAEL, K.C.B., M.P., M.A., M.D., LL.D., D.C.L., Sec.R.S., F.L.S., Professor of Physiology in the University of Cambridge. Great Shelford, Cambridge.

1863. ‡Foster, Robert. The Quarries, Grainger Park-road, Newcastle-upon-Tyne.

1896. ‡Fowkes, F. Hawkshead, Ambleside.

1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.

1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.

1892. ‡Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, E.C.

1883. *Fox, Charles. The Chestnuts, Warlingham, Surrey.

1883. §Fox, Sir CHARLES DOUGLAS, M.Inst.C.E. 28 Victoria-street, Westminster, S.W.

1896. ‡Fox, Henry J. Bank's Dale, Bromborough, near Liverpool.

1883. ‡Fox, Howard, F.G.S. Rosehill, Falmouth.

1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.

1900. *Fox, Thomas. Pyles Thorne House, Wellington, Somerset.

Year of Election.

1881. *FOXWELL, HERBERT S., M.A., F.S.S., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1889. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, E.C.; and Manor House, Richmond, Surrey.
1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S., Professor of Chemistry in the Mason College, Birmingham.
1894. §Franklin, Mrs. E. L. 50 Porchester-terrace, W.
1895. §Fraser, Alexander. 63 Church-street, Inverness.
1882. *Fraser, Alexander, M.B. Professor of Anatomy in the Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1865. *FRASER, JOHN, M.A., M.D., F.G.S. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042, Drexel Building, Philadelphia, U.S.A.
1884. *FREAM, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. 4 Lower Sloane-street, S.W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡FRESHFIELD, DOUGLAS W., F.R.G.S. 1 Airlie-gardens, Campden Hill, W.
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1887. †*Froehlich, The Cavaliere. Grosvenor Terrace, Withington, Manchester.*
1892. *Frost, Edmund, M.B. Chesterfield, Meads, Eastbourne.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. 53 Victoria-road, W.
1899.§§Fry, Edward W. Cannon-street, Dover.
1898. ‡FRY, The Right Hon. Sir EDWARD, D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1898. ‡Fry, Francis J. Leigh Woods, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 17 Upper Belgrave-road, Clifton, Bristol.
1898. ‡Fryer, Alfred C., Ph.D. 13 Eaton-crescent, Clifton, Bristol.
1884. ‡Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1895. ‡FULLARTON, Dr. J. H. Fishery Board for Scotland, George-street, Edinburgh.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, S.E.
1859. ‡FULLER, FREDERICK, M.A. 9 Palace-road, Surbiton.
1869. ‡FULLER, G., M.Inst.C.E. 71 Lexham-gardens, Kensington, W.
1884. ‡Fuller, William, M.B. Oswestry.
1891. ‡Fulton, Andrew. 23 Park-place, Cardiff.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
1887. ‡Gaddum, G. H. Adria House, Toy-lane, Withington, Manchester.
1836. *Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1896. ‡Gair, H. W. 21 Water-street, Liverpool.
1850. ‡GAIRDNER, Sir W. T., K.C.B., M.D., LL.D., F.R.S. Glasgow.

Year of Election.

1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1889. ‡Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. J., M.P. The Cottage, Seymour-grove, Old Trafford, Manchester.
1899. §Galton, Lady Douglas. Himbleton Manor, Droitwich.
1860. *GALTON, FRANCIS, M.A., D.C.L., D.Sc., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. New University Club, St. James's-street, S.W.
1870. §Gamble, Lieut.-Colonel Sir D., Bart., C.B. St. Helens, Lancashire.
1889. ‡Gamble, David. Ratonagh, Colwyn Bay.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. *GAMBLE, J. SYKES, C.I.E., F.R.S., M.A., F.L.S. Highfield, East Liss, Hants.
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S. 8 Avenue du Kursaal, Montreux, Switzerland.
1889. ‡*Gamgee, John. 6 Lingfield Road, Wimbledon, Surrey.*
1899. *Garcke, E. Sunnyside, Bedford Park, Chiswick, W.
1898. §Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
1900. §Gardiner, J. Stanley, M.A. Dunstall, Newton Road, Cambridge.
1887. ‡GARDINER, WALTER, M.A., F.R.S., F.L.S. 45 Hills-road, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.
1896. ‡Gardner, James. The Groves, Grassendale, Liverpool.
1894. ‡Gardner, J. Addyman. 5 Bath-place, Oxford.
1882. ‡GARDNER, JOHN STARKIE. 29 Albert Embankment, S.E.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Spring-gardens, S.W.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. ‡GARSON, J. G., M.D. 14 Stratford Place, W.
1894. *GARSTANG, WALTER, M.A., F.Z.S. Marine Biological Laboratory, Plymouth.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1892. §Garvie, James. Bolton's Park, Potter's Bar.
1889. ‡Garwood, E. J., B.A., F.G.S. Trinity College, Cambridge.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1896. *GASKELL, WALTER HOLBROOK, M.A., M.D., LL.D., F.R.S. The Uplands, Great Shelford, near Cambridge.
1896. §Gatehouse, Charles. Westwood, Noctorum, Birkenhead.
1862. *Gatty, Charles Henry, M.A., LL.D., F.R.S.E., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1890. ‡Gaunt, Sir Edwin. Carlton Lodge, Leeds.
1875. ‡Gavey, J. Hollydale, Hampton Wick, Middlesex.
1892. ‡Geddes, George H. 8 Douglas-crescent, Edinburgh.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. ‡Geddes, John. 33 Portland-street, Southport.

Year of
Election.

1885. ‡GEDDES, Professor PATRICK. Ramsay-garden, Edinburgh.
1887. ‡Gee, W. W. Haldane. Owens College, Manchester.
1867. ‡GEIKIE, Sir ARCHIBALD, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. 10 Chester-terrace, Regent's-park, N.W.
1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. Kilmorie, Colinton-road, Edinburgh.
1898. §Gemmill, James F., M.A., M.B. 16 Dargavel-avenue, Dumbreck, Glasgow.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1875. *George, Rev. Hereford Brooke, M.A., F.R.G.S. Holywell Lodge, Oxford.
1885. ‡Gerard, Robert. Blair-Devenick, Cults, Aberdeen.
1884. *Gerrans, Henry T., M.A. 20 St. John-street, Oxford.
1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1892. ‡Gibson, Francis Maitland. Care of Professor Gibson, 20 George-square, Edinburgh.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., Secretary to the Royal College of Physicians of Edinburgh. 17 Alva-street, Edinburgh.
1896. ‡Gibson, Harvey, M.A., Professor of Botany, University College, Liverpool.
1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.
1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, S.W.
1887. ‡GIFFEN, Sir ROBERT, K.C.B., LL.D., F.R.S., V.P.S.S. Athenæum Club, S.W.
1888. **Gifford, H. J. Lyston Court, Tram Inn, Hereford.*
1898. *Gifford, J. William. Chard.
1884. ‡Gilbert E. E. 245 St. Antoine-street, Montreal, Canada.
1842. GILBERT, Sir JOSEPH HENRY, Ph.D., LL.D., F.R.S., V.P.C.S. Harpenden, near St. Albans.
1883. §Gilbert, Lady. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.
1895. ‡Gilchrist, J. D. F. Carvenon Anstruther, Scotland.
1896. *GILCHRIST, PERCY C., F.R.S., M.Inst.C.E. Frognal Bank, Finchley-road, Hampstead, N.W.
1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove.
1871. *GILL, Sir DAVID, K.C.B., LL.D., F.R.S., F.R.A.S. Royal Observatory, Cape Town.
1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.
1896. ‡Gilmour, H. B. Underlea, Aigburth, Liverpool.
1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1893. *Gimingham, Edward. Stamford House, Northumberland Park, Tottenham.
1900. §Ginsburg, Benedict W., M.A., LL.D. Royal Statistical Society, 9 Adelphi Terrace, W.C.
1867. ‡GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.

Year of Election.

1886. *Gisborne, Hartley, M.Can.S.C.E. Caragana Lodge, Ladysmith, Vancouver Island, Canada.
1850. *Gladstone, George, F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., D.Sc., F.R.S., V.P.C.S. 17 Pembridge-square, W.
1883. *Gladstone, Miss. 17 Pembridge-square, W.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. The Shola, Heathfield-road, South Croydon.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. Trinity College, Cambridge.
1897. ‡Glashan, J. C., LL.D. Ottawa, Canada.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S., Director of the National Physical Laboratory. 23 Queen's Road, Richmond.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, W.
1859. ‡Glennie, J. S. Stuart, M.A. Verandah Cottage, Haslemere, Surrey.
1867. ‡*Gloag, John A. L. 10 Inverleith Place, Edinburgh.*
1874. ‡Glover, George T. Corby, Hoylake.
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1899. §Godfrey, Ingram F. Brook House, Ash, Dover.
1886. ‡Godlee, Arthur. The Lea, Harborne, Birmingham.
1887. ‡Godlee, Francis. 8 Minshall-street, Manchester.
1878. *Godlee, J. Lister. 3 Clarence-terrace, Regent's Park, N.W.
1880. ‡GODMAN, F. DU CANE, D.C.L., F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. ‡GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.G.S., F.R.G.S., F.Z.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1898. §Goldney, F. B. Goodnestone Park, Dover.
1881. ‡GOLDSCHMIDT, EDWARD, J.P. Nottingham.
1886. ‡GOLDSMID, Major-General Sir F. J., K.C.S.I., C.B., F.R.G.S. Godfrey House, Hollingbourne.
1899.§§Gomme, G. L., F.S.A. 24 Dorset-square, N.W.
1890. *GONNER, E. C. K., M.A., Professor of Political Economy in University College, Liverpool.
1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1885. ‡GOODMAN, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1884. *Goodridge, Richard E. W. Lupton, Michigan, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1885. ‡Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1893. ‡Gordon, Mrs. M. M., D.Sc. 1 Rubislaw-terrace, Aberdeen.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. Ferndale, Babington Road, Streatham, S.W.
1899. §Gordon, T. Kirkman. 15 Hampden Street, Nottingham.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1887. ‡*Gordon, William John. 3 Lavender-gardens, S.W.*

Year of
Election.

1865. ‡Gore, George, LL.D., F.R.S. 20 Easy-row, Birmingham.
1875. *Gotch, Francis, M.A., B.Sc., F.R.S., Professor of Physiology in the University of Oxford. The Lawn, Banbury-road, Oxford.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1894. ‡Gould, G. M., M.D. 119 South 17th-street, Philadelphia, U.S.A.
1888. ‡Gouraud, Colonel. Gwydyr Mansions, Hove, Sussex.
1901. §Gourlay, Robert. (Local Treasurer.) Glasgow.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill Gardens, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill Gardens, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.
1875. ‡Grahame, James. 12 St. Vincent-street, Glasgow.
1892. ‡Grange, C. Ernest. 57 Berners-street, Ipswich.
1893. ‡Granger, Professor F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1892. ‡Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F., M.Inst.C.E., F.G.S. Northumberland-chambers, Northumberland-avenue, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1899. §§Gray, Albert Alexander. 16 Berkeley-terrace, Glasgow.
1890. ‡Gray, Andrew, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1899. §§Gray, Charles. 11 Portland-place, W.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1893. ‡Gray, J. C., General Secretary of the Co-operative Union, Limited, Long Millgate, Manchester.
1892. *Gray, James Hunter, M.A., B.Sc. 141 Hopton Road, Streatham, S.W.
1870. ‡Gray, J. Macfarlane. 4 Ladbroke-crescent, W.
1892. §Gray, John, B.Sc. 351 Coldharbour-lane, Brixton, S.W.
1887. ‡Gray, Joseph W., F.G.S. St. Elmo, Leckhampton-road, Cheltenham.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. Glenburn Park, Belfast.
*Gray, Colonel William. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Gray, Mrs. W. L. Westmoor Hall, Brimsdown, Middlesex.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, N.W.
1872. *Grece, Clair J., LL.D. 94 Station Road, Redhill, Surrey.
1888. §Green, J. Reynolds, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany to the Pharmaceutical Society of Great Britain. Arncliffe, Grange-road, Cambridge.
1887. ‡*Greene, Friese.* 162 *Sloane-street, S.W.*

Year of Election.

1882. ‡Greenhill, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 10 New Inn, W.C.
1881. ‡Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, N.W.
1898. *Greenly, Edward. Achnashean, near Bangor, North Wales.
1884. ‡Greenshields, E. B. Montreal, Canada.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C., jun. Driffield, near Derby.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1890. ‡Greenwood, Arthur. Cavendish-road, Leeds.
1875. ‡Greenwood, F., M.B. Brampton, Chesterfield.
1877. ‡*Greenwood, Holmes. 78 King Street, Accrington.*
1887. ‡Greenwood, W. H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1894. *Gregory, J. Walter, D.Sc., F.G.S. 3 Aubrey-road, Kensington, W.
1896. §Gregory, R. A. The Homestead, Westover-road, Wandsworth Common, S.W.
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William, F.G.S. Baldersby, S.O., Yorkshire.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1836. Griffin, S. F. Albion Tin Works, York-road, N.
1894. *Griffith, C. L. T., Assoc. M.Inst.C.E. College-road, Harrow, Middlesex.
1859. *Griffith, G. (Assistant General Secretary.) College-road, Harrow, Middlesex.
1884. ‡Griffiths, E. H., M.A., F.R.S. 12 Park-side, Cambridge.
1884. ‡Griffiths, Mrs. 12 Park-side, Cambridge.
1891. ‡Griffiths, P. Rhys, B.Sc., M.B. 71 Newport-road, Cardiff.
1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1870. ‡Grimsdale, T. F., M.D. Hoylake, Liverpool.
1888. *Grimshaw, James Walter, M.Inst.C.E. Australian Club, Sydney, New South Wales.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1894. ‡Groom, Professor P., M.A., F.L.S. Hollywood, Egham, Surrey.
1894. §Groom, T. T., D.Sc. The Poplars, Hereford.
1896. ‡Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1892. ‡Grove, Mrs. Lilly, F.R.G.S. Mason College, Birmingham.
1891. ‡Grover, Henry Llewellin. Clydach Court, Pontypridd.
1863. *Groves, Thomas B. Broadley, Westerhall-road, Weymouth.
1869. ‡Grubb, Sir Howard, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1897. ‡Grünbaum, A. S., M.A., M.D. 45 Ladbroke Grove, W.
1897. §Grünbaum, O. F. F., B.A., D.Sc. 45 Ladbroke Grove, W.
1886. ‡Grundy, John. 17 Private-road, Mapperley, Nottingham.
1891. ‡Grylls, W. London and Provincial Bank, Cardiff.
1887. ‡Guillemard, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1891. ‡Gunn, Sir John. Llandaff House, Llandaff.
1877. ‡Gunn, William, F.G.S. Office of the Geological Survey of Scotland, Sheriff's Court House, Edinburgh.
1866. ‡Günther, Albert C. L. G., M.A., M.D., Ph.D., F.R.S., Pres.L.S., F.Z.S. 22 Lichfield-road, Kew, Surrey.

Year of Election.

1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1883. ‡Guthrie, Malcolm. Prince's-road, Liverpool.
1896. ‡Guthrie, Tom, B.Sc. Yorkshire College, Leeds.
1876. ‡GWYTHER, R. F., M.A. Owens College and 33 Heaton Road, Withington, Manchester.

1884. ‡Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *HADDON, ALFRED CORT, M.A., F.R.S., F.Z.S. Inisfail, Hills-road, Cambridge.
1842. Hadfield, George. Victoria Park, Manchester.
1888. *Hadfield, R. A., M.Inst.C.E. The Grove, Endcliffe Vale-road, Sheffield.
1892. ‡Haigh, E., M.A. Longton, Staffordshire.
1870. ‡Haigh, George. 27 Highfield South, Rockferry, Cheshire.
1879. ‡HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.
1883. ‡HALIBURTON, R. G., Q.C. 13 Pall Mall, S.W.
1899. §Hall, A. D. South-Eastern Agricultural College, Wye, Kent.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, W.C.
1854. *HALL, HUGH FERGIE, F.G.S. Cowley House, Headington Hill, Oxford.
1898. §Hall, J. P. The 'Tribune,' New York, U.S.A.
1887. ‡*Hall, John. Springbank, Leftwich, Northwich.*
1899. §Hall, John, M.D. National Bank of Scotland, 37 Nicholas-lane, E.C.
1885. §Hall, Samuel, F.I.C., F.C.S. 19 Aberdeen-park, Highbury, N.
1900. §Hall, T. Farmer, F.R.G.S. 39 Gloucester Square, Hyde Park, W.
1896. §Hall, Thomas B. Larch Wood, Rockferry, Cheshire.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1896. ‡Hall-Dare, Mrs. Caroline. 13 Great Cumberland-place, W.
1891. *Hallett, George. Cranford, Victoria-road, Penarth, Glamorganshire.
1891. §Hallett, J. H., M.Inst.C.E. Maindy Lodge, Cardiff.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., F.R.S., Professor of Physiology in King's College, London. Church Cottage, 17 Marylebone-road, W.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Fairley, Weston, Bath.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 41 Queen's-road, Aberdeen.
1881. *Hammond, Robert. 64 Victoria-street, Westminster, S.W.
1899. *Hanbury, Daniel. La Mortola, Ventimiglia, Italy.
1892. ‡Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878.§§Hance, Edward M., LL.B. Municipal Offices, Liverpool.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, S.W.
1897. ‡HANCOCK, HARRIS. University of Chicago, U.S.A.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, E.C.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. ‡Hannaford, E. P., M.Inst.C.E. 2573 St. Catherine-street, Montreal, Canada.
1894. §Hannah, Robert, F.G.S. 82 Addison-road, W.
1886. §Hansford, Charles, J.P. Englefield House, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., F.C.S. Cowley Grange, Oxford.

Year of
Election.

1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. 6 Queen Anne's-gate, S.W.
1900. §Harcourt, Hon. R., Q.C., Minister of Education for the Province of Ontario, Toronto, Canada.
1886. *Hardcastle, Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1892. *Harden, Arthur, Ph.D., M.Sc. Jenner Institute of Preventive Medicine, Chelsea Gardens, Grosvenor Road, S.W.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1894. ‡Hardman, S. C. 225 Lord-street, Southport.
1897. ‡HARDY, Hon. ARTHUR S., Toronto, Canada.
1894. ‡Hare, A. T., M.A. Neston Lodge, East Twickenham, Middlesex.
1894. ‡Hare, Mrs. Neston Lodge, East Twickenham, Middlesex.
1898. ‡Harford, W. H. Oldown House, Almondsbury.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. ‡Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. §HARKER, ALFRED, M.A., F.G.S. St. John's College, Cambridge.
1896. ‡Harker, Dr. John Allen. Springfield House, Stockport.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W., M.D. California Academy of Sciences, San Francisco, California, U.S.A.
1871. ‡Harkness, William, F.C.S. 1 St. Mary's-road, Canonbury, N.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton.
1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest Hill, S.E.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, W.C.
1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest Hill, S.E.
1899. §Harman, Dr. N. Bishop. St. John's College, Cambridge.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., M.A., B.Sc., F.R.S. King's College, Cambridge.
1882. ‡*Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.*
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., F.G.S., Professor of Chemistry and Mineralogy in McGill University, Montreal. University-street, Montreal, Canada.
1872. *Harris, Alfred. Warfenden, Farnborough, Hants.
1888. ‡Harris, C. T. 4 Kilburn Priory, N.W.
1842. *Harris, G. W., M.Inst.C.E. Millicent, South Australia.
1889. §HARRIS, H. GRAHAM, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1898. ‡Harrison, A. J., M.D. Failand Lodge, Guthrie-road, Clifton, Bristol.
1888. ‡Harrison, Charles. 20 Lennox-gardens, S.W.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1864. ‡*Harrison, George. Barnsley, Yorkshire.*
1889.§§Harrison, J. C. Oxford House, Castle-road, Scarborough.
1858. *HARRISON, J. PARK, M.A. 22 Connaught-street, Hyde Park, W.
1892. ‡HARRISON, JOHN. Rockville, Napier-road, Edinburgh.
1870. ‡HARRISON, REGINALD, F.R.C.S. 6 Lower Berkeley-street, Portman-square, W.

Year of Election.

1853. ‡Harrison, Robert. 36 George-street, Hull.
1892. ‡Harrison, Rev. S. N. Ramsey, Isle of Man.
1895. ‡Harrison, Thomas. 48 High-street, Ipswich.
1886. ‡Harrison, W. Jerome, F.G.S. Board School, Icknield-street, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
1893. *Hartland, E. Sidney, F.S.A. Highgarth, Gloucester.
1897. ‡Hartley, E. G. S. Wheaton Astley Hall, Stafford.
1871. *Hartley, Walter Noel, F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin. 36 Waterloo-road, Dublin.
1896. ‡Hartley, W. P., J.P. Aintree, Liverpool.
1886. *Hartog, Professor M. M., D.Sc. Queen's College, Cork.
1887. ‡Hartog, P. J., D.Sc. Owens College, Manchester.
1897. ‡Harvey, Arthur. Rosedale, Toronto, Canada.
1898. ‡Harvey, Eddie. 10 The Paragon, Clifton, Bristol.
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
1875. *Hastings, G. W. Elm Lodge, Dartford Heath, Bexley, Kent.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 28 Jermyn-street, S.W.
1893. ‡Hatton, John L. S. People's Palace, Mile End-road, E.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *Hawkshaw, John Clarke, M.A., M.Inst.C.E., F.G.S. 2 Down-street, W., and 33 Great George-street, S.W.
1897. §Hawksley, Charles. 60 Porchester-terrace, W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889. ‡Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡*Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.*
1890. ‡Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *Hay, Admiral the Right Hon. Sir John C. D. Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, S.W.
1885. *Haycraft, John Berry, M.D., B.Sc., F.R.S.E., Professor of Physiology, University College, Cardiff.
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1900. §Hayden, H. H. The Oaks, Londonderry.
1894. ‡Hayes, Edward Harold. 5 Rawlinson-road, Oxford.
1896. ‡Hayes, Rev. F. C. The Rectory, Raheny, Dublin.
1896. ‡Hayes, William. Fernyhurst, Rathgar, Dublin.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1898. ‡Hayman, C. A. Kingston Villa, Richmond Hill, Clifton, Bristol.
1858. *Hayward, R. B., M.A., F.R.S. Ashcombe, Shanklin, Isle of Wight.
1896. *Haywood, A. G. Rearsby, Merrilocks-road, Blundellsands.
1879. *Hazelhurst, George S. The Grange, Rockferry.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. ‡Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1883. *Heap, Ralph. 1 Brick-court, Temple, E.C.
1883. ‡Heape, Charles. Tovrak, Oxton, Cheshire.
1883. ‡Heape, Joseph R. Globe House, Rochdale.
1882. *Heape, Walter, M.A. Heyroun, Chaucer-road, Cambridge.

Year of Election.

1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1898. *Heath, Arthur J. 10 Grove Road, Redland, Bristol.
1898. ‡Heath, R. S., M.A., D.Sc. Mason University College, Birmingham.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Edinburgh.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1865. ‡Heaton, Harry. Harborne House, Harborne, Birmingham.
1892. *HEATON, WILLIAM H., M.A., Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West. 7 Grafton-road, Whitley, Newcastle-upon-Tyne.
1884. §Heaviside, Rev. George, B.A., F.R.G.S., F.R.Hist.S. 7 Grosvenor-street, Coventry.
1888. *Heawood, Edward, M.A. 3 Underhill-road, Lordship-lane, S.E.
1888. *Heawood, Percy J., Lecturer in Mathematics at Durham University. 41 Old Elvet, Durham.
1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. Wootton Lodge, 39 Streatham-hill, S.W.
1881. *HELE-SHAW, H. S., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in University College, Liverpool. 27 Ullet-road, Liverpool.
1887. §Hembry, Frederick William, F.R.M.S. Langford, Sidcup, Kent.
1897. §Hemming, G. W., Q.C. 2 Earl's Court-square, S.W.
1899. §Hemsalech, G. A. Faculté des Sciences, Paris.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Henderson, Mrs. A. L. Westmoor Hall, Brimsdown, Middlesex.
1891. *HENDERSON, G. G., D.Sc., M.A., F.C.S., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College. 204 George-street, Glasgow.
1892. ‡Henderson, John. 3 St. Catherine-place, Grange, Edinburgh.
1885. ‡Henderson, Sir William. Devanha House, Aberdeen.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall-mansions, Kensington, S.W.
1896. ‡Henderson, W. Saville, B.Sc. Beech Hill, Fairfield, Liverpool.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A. Palazzo Ferruzzi, Zattere, Venice.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S., Professor of Mechanics and Mathematics in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 34 Clarendon-road, Notting Hill, W.
Henry, Franklin. Portland-street, Manchester.
Henry, Mitchell. Stratheden House, Hyde Park, W.
1892. ‡HEPBURN, DAVID, M.D., F.R.S.E. The University, Edinburgh.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Oakfield Cottage, Dartford Heath, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, W.
1890. ‡Hepper, J. 43 Cardigan-road, Headingley, Leeds.
1890. ‡Hepworth, Joseph. 25 Wellington-street, Leeds.
1892. *HERBERTSON, ANDREW J., Ph.D., F.R.S.E., F.R.G.S. 25 Norham Road, Oxford.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in University College, Liverpool. Croxteth Lodge, Sefton Park, Liverpool.

Year of Election.

1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, Liverpool.
1891. ‡Hern, S. South Cliff, Marine Parade, Penarth.
1871. *HERSCHEL, ALEXANDER S., M.A., D.C.L., F.R.S., F.R.A.S., Honorary Professor of Physics and Experimental Philosophy in the University of Durham. Observatory House, Slough, Bucks.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1900. *Herschel, J. C. W. Littlemore, Oxford.
1900. *Herschel, Sir W. J., Bart. Littlemore, Oxford.
1895. §Hesketh, James. Scarisbrick Avenue-buildings, 107 Lord-street, Southport.
1894. ‡HEWETSON, G. H. 39 Henley-road, Ipswich.
1894. ‡Hewins, W. A. S., M.A., F.S.S. Professor of Political Economy in King's College, Strand, W.C.
1896. §Hewitt, David Basil. Oakleigh, Northwich, Cheshire.
1893. ‡Hewitt, Thomas P. Eccleston Park, Prescot, Lancashire.
1883. ‡Hewson, Thomas. Junior Constitutional Club, Piccadilly, W.
1882. ‡HEYCOCK, CHARLES T., M.A., F.R.S. King's College, Cambridge.
1883. §Heyes, Rev. John Frederick, M.A., F.R.G.S. 90 Arkwright Street, Bolton.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1897. ‡Heys, Thomas. 130 King-street West, Toronto, Canada.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
1879. ‡Heywood, Sir A. Percival, Bart. Duffield Bank, Derby.
1886. §§HEYWOOD, HENRY, J.P., F.C.S. Witla Court, near Cardiff.
1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.
1888. ‡Hichens, James Harvey, M.A., F.G.S. The School House, Wolverhampton.
1898. §Hicks, Henry B. 44 Pembroke-road, Clifton, Bristol.
1877. §HICKS, Professor W. M., M.A., D.Sc., F.R.S., Principal of University College, Sheffield.
1886. ‡Hicks, Mrs. W. M. Dunheved, Endcliffe-crescent, Sheffield.
1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.
1887. *HICKSON, SYDNEY J., M.A., D.Sc., F.R.S., Professor of Zoology in Owens College, Manchester.
1864. *HIERN, W. P., M.A. The Castle, Barnstaple.
1891. §HIGGS, HENRY, LL.B., F.S.S. 12 Lyndhurst-road, Hampstead, N.W.
1894. §Hill, Rev. A. Du Boulay. East Bridgford Rectory, Nottingham.
1885. *HILL, ALEXANDER, M.A., M.D. Downing College, Cambridge.
1898. ‡Hill, Charles. Clevedon.
*Hill, Rev. Canon Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1881. *HILL, Rev. EDWIN, M.A., F.G.S. The Rectory, Cockfield, Bury St. Edmunds.
1887. ‡Hill, G. H., F.G.S. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, W.C.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1898. *Hill, Thomas Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *HILLHOUSE, WILLIAM, M.A., F.L.S., Professor of Botany in Mason Science College. 16 Duchess-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, near Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.

Year of Election.

1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1870. ‡HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
1886. ‡Hingley, Sir Benjamin, Bart. Hatherton Lodge, Cradley, Worcestershire.
1881. ‡Hingston, J. T. Clifton, York.
1884. ‡HINGSTON, Sir WILLIAM HALES, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1900. §Hinks, Arthur R., M.A. 10 Huntingdon Road, Cambridge.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1899. §Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1879. ‡Hobkirk, Charles P., F.L.S. The Headlands, Scotland-lane, Horsforth, near Leeds.
1887. *Hobson, Bernard, B.Sc., F.G.S. Thornton, Parkfield Road, Didsbury.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, W.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1883. ‡*Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.*
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1863. *HODGKIN, THOMAS, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1896. ‡Hodgkinson, Arnold. 16 Albert-road, Southport.
1880. §Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 18 Glencoe-road, Blackheath, S.E.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1898. §Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.
1896. ‡Hodgson, Dr. Wm., J.P. Helensville, Crewe.
1894. ‡Hogg, A. F., M.A. 13 Victoria-road, Darlington.
1894.§§Holah, Ernest. 5 Crown-court, Cheapside, E.C.
1883. ‡*Holden, Edward. Laurel Mount, Shipley, Yorkshire.*
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1887. *Holder, Henry William, M.A. Owens College, Manchester.
1896. ‡Holder, Thomas. 2 Tithebarn-street, Liverpool.
1900. §Holdich, Col. Sir Thomas H., R.E., K.C.I.E. Army and Navy Club, 36 Pall Mall, S.W.
1887. *Holdsworth, C. J. Hill Top, near Kendal, Westmoreland.
1891. §Holgate, Benj., F.G.S. The Briars, North Park Avenue, Roundhay.
1879. ‡Holland, Calvert Bernard. Hazel Villa, Thicket-road, Anerley, S.E.
1896. §Holland, Mrs. Lowfields House, Hooton.
1898. ‡Holland, Thomas H., F.G.S. Geological Survey Office, Calcutta.
1889. ‡Holländer, Bernard. King's College, Strand, W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 24 Aberdare-gardens, West Hampstead, N.W.
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.

Year of Election.

1896. ‡Holt, William Henry. 11 Ashville-road, Birkenhead.
1897. ‡Holterman, R. F. Brantford, Ontario, Canada.
1891. *Hood, Archibald, M.Inst.C.E. Sherwood, Cardiff.
1875. *Hood, John. Chesterton, Cirencester.
1847. ‡Hooker, Sir Joseph Dalton, G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. The Camp, Sunningdale, Berkshire.
1892. ‡Hooker, Reginald H., M.A. 3 Gray's Inn-place, W.C.
1865. *Hooper, John P. Deepdene, Rutford-road, Streatham, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.
1884. *Hopkinson, Charles. The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.
1871. *Hopkinson, John, F.L.S., F.G.S., F.R.Met.Soc. 84 New Bond Street, W.; and Westwood, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
1891. ‡Horder, T. Garrett. 10 Windsor-place, Cardiff.
1898. *Hornby, R., M.A. The High School, Newcastle, Staffordshire.
1885. ‡Horne, John, F.R.S.E., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1875. *Horniman, F. J., M.P., F.R.G.S., F.L.S. Falmouth House, 20 Hyde Park-terrace, W.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *Horsley, Victor A. H., B.Sc., F.R.S., F.R.C.S. 25 Cavendish-square, W.
1884. *Hotblack, G. S. Brundall, Norwich.
1899. §§Hotblack, J. T. 45 Newmarket-road, Norwich.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S. Royal Observatory, Cape Town.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.
1896. ‡Hoult, J. South Castle-street, Liverpool.
1884. ‡Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
1893. ‡Howard, F. T., M.A., F.G.S. University College, Cardiff.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1899. §Howard-Hayward, H. Harbledown, 120 Queen's-road, Richmond, Surrey.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1899. §§Howden, Ian D. C. 6 Cambridge-terrace, Dover.
1889. ‡Howden, Robert, M.B., Professor of Anatomy in the University of Durham College of Medicine, Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S., Late Director of the Geological Survey of Great Britain.
1898. ‡Howell, J. H. 104 Pembroke-road, Clifton, Bristol.
1891. ‡Howell, Rev. William Charles, M.A. Holy Trinity Parsonage, High Cross, Tottenham, Middlesex.
1886. § Howes, G. B., LL.D., F.R.S., F.L.S. Professor of Zoology in the Royal College of Science, South Kensington, S.W.
1884. ‡Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.

Year of Election.

1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. 7 Prince's Buildings, Clifton, Bristol.
1863. ‡HOWORTH, Sir H. H., K.C.I.E., M.P., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1887. §HOYLE, WILLIAM E., M.A. Owens College, Manchester.
1888. ‡Hudd, Alfred E., F.S.A. 94 Pembroke-road, Clifton, Bristol.
1898. §HUDLESTON, W. H., M.A., F.R.S., F.G.S. 8 Stanhope-gardens, S.W.
1888. ‡HUDSON, C. T., M.A., LL.D., F.R.S. Briar Knoll, Lake, Sandown, Isle of Wight.
1894. §Hudson, John E. 125 Milk-street, Boston, Massachusetts, U.S.A.
1867. *HUDSON, WILLIAM H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenberg-gardens, Clapham Common, S.W.
1858. *HUGGINS, Sir WILLIAM, K.C.B., D.C.L. Oxon., LL.D. Camb., Pres.R.S., F.R.A.S. 90 Upper Tulse-hill, S.W.
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. ‡Hughes, Miss E. P. Cambridge Teachers' College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1896. ‡Hughes, John W. New Heys, Allerton, Liverpool.
1870. **Hughes, Lewis. Fenwick-chambers, Liverpool.*
1891. ‡Hughes, Thomas, F.C.S. 31 Loudoun-square, Cardiff.
1868. §HUGHES, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge. 18 Hills-road Cambridge.
1891. ‡Hughes, Rev. W. Hawker. Jesus College, Oxford.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. 20 Arundel-gardens Notting Hill, W.
1897. ‡Hume, J. G., M.A., Ph.D. 650 Church-street, Toronto, Canada.
1887. *HUMMEL, Professor J. J. 152 Woodsley-road, Leeds.
1890 ‡Humphrey, Frank W. 63 Prince's-gate, S.W.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1891. ‡Hunt, D. de Vere, M.D. Westbourne-crescent, Sophia-gardens, Cardiff.
1875. *Hunt, William. North Cote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael. Greystones, Sheffield.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, W.C.
1885. ‡Huntly, The Most Hon. the Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1898. ‡Hurle, J. Cooke. Southfield House, Brislington, Bristol.
1869. ‡Hurst, George. Bedford.
1882. *Hurst, Walter, B.Sc. Kirkgate, Tadcaster, Yorkshire.
1861. *Hurst, William John. Drumaness, Ballynahinch, Co. Down, Ireland.

Year of Election.

1887. ‡*Husband, W. E. 56 Bury New-road, Manchester.*
1882. ‡*Hussey, Major E. R., R.E. 24 Waterloo-place, Southampton.*
1894. *Hutchinson, A. Pembroke College, Cambridge.
1896. ‡Hutchinson, W. B. 4 West-street, Southport.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.
1900. *Hyndman, H. H., Francis. Physical Laboratory, Leiden, Netherlands.

1883. §Idris, T. H. W. Pratt-street, Camden Town, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F., C.B., C.M.G., M.A. British Guiana.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1893. ‡Ingle, Herbert. Pool, Leeds.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡*Innes, John. The Limes, Alcester Road, Moseley, Birmingham.*
1898. ‡Inskip, James. Clifton Park, Clifton, Bristol.
1892. ‡*Ireland, D. W. 10 South Gray Street, Edinburgh.*
1892. ‡Irvine, James. Devonshire-road, Birkenhead.
1892. ‡Irvine, Robert, F.R.S.E. Royston, Granton, Edinburgh.
1882. §IRVING, Rev. A., B.A., D.Sc., F.G.S. Hockerill Vicarage, Bishop's Stortford, Herts.
1888. **Isaac, J. F. V., B.A. Royal York Hotel, Brighton.*
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡*Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, W.*
1886. ‡Izod, William. Church-road, Edgbaston, Birmingham.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. ‡Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *JACK, WILLIAM, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. *JACKSON, Professor A. H., B.Sc. 358 Collins-street, Melbourne, Australia.
1883. ‡*Jackson, Frank. 11 Park-crescent, Southport.*
1874. *Jackson, Frederick Arthur. Penalva Ranche, Millarville, Alberta, Calgary, N.W.T., Canada.
1883. *Jackson, F. J. 42 Whitworth-street, Manchester.
1883. ‡Jackson, Mrs. F. J. 42 Whitworth-street, Manchester.
1899. §Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1897. §Jackson, James, F.R.Met.Soc. 34 Lonsdale-square, N.
1898. *Jackson, Sir John. 3 Victoria-street, S.W.
1869. §Jackson, Moses, J.P. The Orchards, Whitchurch, Hants.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.

Year of
Election.

1874. *Jaffe, John. Villa Jaffe, 38 Prom. des Anglais, Nice, France.
1865. *Jaffray, Sir John, Bart. Park-grove, Edgbaston, Birmingham.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry. 64 Park-place, Cardiff.
1891. *James, Charles Russell. 6 New-court, Lincoln's Inn, W.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1891. ‡James, Ivor. University College, Cardiff.
1891. ‡*James, John Herbert. Howard House, Arundel-street, Strand, W.C.*
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.
1896. ‡James, O. S. 192 Jarvis-street, Toronto, Canada.
1858. ‡James, William C. Woodside, Plymouth.
1896. **Jameson, H. Lyster. Killencoole, Castlebellingham, Ireland.*
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1887. ‡Jamieson, G. Auldjo. 37 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
1889. *JAPP, F. R., M.A., Ph.D., LL.D., F.R.S., V.P.C.S., Professor of Chemistry in the University of Aberdeen.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. 9 Winton-drive, Kelvinside, Glasgow.
1897. ‡Jeffrey, E. C., B.A. The University, Toronto, Canada.
1867. ‡Jeffreys, Howel, M.A. 61 Bedford-gardens, Kensington, W.
1894. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1891. §Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. Royal College of Science, South Kensington, S.W.
1873. §Jenkins, Major-General J. J. 16 St. James's-square, S.W.
1880. *JENKINS, Sir JOHN JONES. The Grange, Swansea.
1899. §Jenkins, Colonel T. M. Glan Tivy, Westwood-road, Southampton.
1852. ‡Jennings, Francis M., M.R.I.A. Brown-street, Cork.
1893. §Jennings, G. E. Glen Helen, Narborough Road, Leicester.
1897. §§Jennings, W. T., M.Inst.CE. Molson's Bank Buildings, Toronto, Canada.
1878. ‡*Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.*
1899. §§Jepson, Thomas. Evington, Northumberland-street, Higher Broughton, Manchester.
1887. ‡JERVIS-SMITH, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
Jessop, William. Overton Hall, Ashover, Chesterfield.
1889. ‡Jevons, F. B., M.A. The Castle, Durham.
1900. *Jevons, H. Stanley. 95 Victoria Road, Cambridge.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1891. ‡*John, E. Cowbridge, Cardiff.*
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. ‡JOHNSON, ALEXANDER, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1883. ‡Johnson, Ben. Micklegate, York.
1871. *Johnson, David, F.C.S., F.G.S. 1 Victoria-road, Clapham Common, S.W.
1883. ‡*Johnson, Edmund Litler. 73 Albert Road, Southport.*
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.

Year of Election.

1888. ‡Johnson, J. G. Southwood Court, Highgate, N.
1870. ‡Johnson, Richard C., F.R.A.S. 46 Jermyn-street, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.
1890. *JOHNSON, THOMAS, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1898. *Johnson, W. Claude, M.Inst.C.E. The Dignaries, Blackheath, S.E.
1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1899. §Johnston, Colonel Duncan A., R.E. Ordnance Survey, Southampton.
1883. ‡JOHNSTON, Sir H. H., K.C.B., F.R.G.S. Queen Anne's Mansions, S.W.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, N.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883. ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡JOHNSTON-LAVIS, H. J., M.D., F.G.S. Beaulieu, Alpes Maritimes, France.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. ‡JOLLY, WILLIAM, F.R.S.E., F.G.S. St. Andrew's-road, Pollokshields, Glasgow.
1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.
1896. *JOLY, C. J., M.A. The Observatory, Dunsink, Co. Dublin.
1888. ‡JOLY, JOHN, M.A., D.Sc., F.R.S., Professor of Geology and Mineralogy in the University of Dublin.
1898. ‡Jones, Alfred L. Care of Messrs. Elder, Dempster, & Co., Liverpool.
1881. ‡*Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.*
1887. ‡Jones, D. E., B.Sc., H.M. Inspector of Schools. Science and Art Department, South Kensington, S.W.
1890. §JONES, Rev. EDWARD, F.G.S. Primrose Cottage, Embsay, Skipton.
1891. ‡Jones, Dr. Evan. Aberdare.
1896. ‡Jones, E. Taylor. University College, Bangor.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, 21 Cambridge Road, Waterloo, Liverpool.
1895. ‡Jones, Harry. Engineer's Office, Great Eastern Railway, Ipswich.
1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, S.W.
1881. *JONES, J. VIRIAMU, M.A., B.Sc., F.R.S., Principal of the University College of South Wales and Monmouthshire, Cardiff.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. 17 Parson's Green, Fulham, S.W.
1896. §Jones, W. Hope Bank, Lancaster-road, Pendleton, Manchester.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1891. ‡*Jones, William Lester. 22 Newport-road, Cardiff.*
1875. *Jose, J. E. 49 Whitechapel, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.

Year of Election.

1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1879. ‡Jowitt, A. Scotia Works, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, S.W.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1896. ‡Joyce, Joshua. 151 Walton-street, Oxford.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1848. **Jubb, Abraham. Halifax.*
1870. ‡Judd, John Wesley, C.B., F.R.S., F.G.S., Professor of Geology in the Royal College of Science, London. 22 Cumberland-road, Kew.
1883. ‡Justice, Philip Middleton. 14 Southampton-buildings, Chancery-lane, W.C.

1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. 3 Lindenallee, Westend, Berlin.
1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.
1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.
1894. ‡*Keene, Captain C. T. P., F.Z.S. 11 Queen's-gate, S.W.*
1894. ‡Keightley, Rev. G. W. Great Stambridge Rectory, Rochford, Essex.
1892. ‡*Keiller, Alexander, M.D., LL.D., F.R.S.E. 54 Northumberland-street, Edinburgh.*
1878. *Kelland, W. H. North Street, Exeter.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. Ermington, Taunton, Somerset.
1885. §Keltie, J. Scott, LL.D., Sec. R.G.S., F.S.S. 1 Savile-row, W.
1847. *Kelvin, The Right Hon. Lord, G.C.V.O., M.A., LL.D., D.C.L., F.R.S., F.R.S.E., F.R.A.S. Netherhall, Largs, Ayrshire.
1877. *Kelvin, Lady. Netherhall, Largs, Ayrshire.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1898. *Kemp, John T., M.A. 61 Cotham Brow, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1890. §Kempson, Augustus. Kildare, 17 Arundel-road, Eastbourne.
1891. §Kendall, Percy F., F.G.S., Professor of Geology in Yorkshire College, Leeds.
1875. ‡Kennedy, Alexander B. W., F.R.S., M.Inst.C.E. 17 Victoria-street, S.W., and 1 Queen Anne-street, Cavendish-square, W.
1897. §Kennedy, George, M.A., LL.D. Crown Lands Department, Toronto, Canada.
1884. ‡Kennedy, George T., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.
1876. ‡Kennedy, Hugh. 20 Mirkland-street, Glasgow.
1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.
1884. ‡Kennedy, William. Hamilton, Ontario, Canada.
1897. ‡*Kenrick, Frank B. Knesebeckstr. 3iii., Charlottenburg, Berlin.*
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
1893. §Kent, A. F. Stanley, M.A., F.L.S., F.G.S., Professor of Physiology in University College, Bristol.
1886. §Kenward, James, F.S.A. 43 Streatham High-road, S.W.

Year of Election.

1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. ‡KERMODE, PHILIP M. C. Hillside, Ramsey, Isle of Man.
1884. ‡Kerr, James, M.D. Winnipeg, Canada.
1887. ‡Kerr, James. Dunkenhalgh, Accrington.
1883. ‡KERR, REV. JOHN, LL.D., F.R.S. Free Church Training College, Glasgow.
1892. ‡Kerr, J. Graham. Christ's College, Cambridge.
1889. ‡Kerry, W. H. R. The Sycamores, Windermere.
1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.
1869. *Kesselmeyer, Charles A. Rose Villa, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Rivington View, Hale Road, Bowdon, Cheshire.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.
1886. §KIDSTON, ROBERT, F.R.S.E., F.G.S. 12 Clarendon-place, Stirling.
1897. ‡Kiekelly, Dr. John, LL.D. 46 Upper Mount-street, Dublin.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1896. *Killey, George Deane. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡Kimmins, C. W., M.A., D.Sc. Downing College, Cambridge.
1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Dublin.
1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.
1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1883. *King, Francis. Alabama, Penrith.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1899. ‡KING, Sir GEORGE, K.C.I.E., F.R.S. Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Stonelands, West Hoathley.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
1883. *King, Joseph. Lower Birtley, Witley, Godalming.
1860. *King, Mervyn Kersteman. Merchants' Hall, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. ‡King, Sir William. Stratford Lodge, Southsea.
1897. ‡Kingsmill, Nichol. Toronto, Canada.
1875. ‡KINGZETT, CHARLES T., F.C.S. Elmstead Knoll, Chislehurst.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. 2 Moray Place, Edinburgh.
1900. *KIPPING, Professor F. STANLEY, D.Sc., Ph.D., F.R.S. University College, Nottingham.
1899. *Kirby, Miss C. F. 74 Kensington Park-road, W.
1899. *Kirby, Miss M. A. Field House, Richmond Road, Montpelier, Bristol.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *KITSON, Sir JAMES, Bart., M.P. Gledhow Hall, Leeds.
1886. ‡Klein, Rev. L. M. de Beaumont, D.Sc., F.L.S. 6 Devonshire-road, Liverpool.
1886. ‡Knight, J. McK., F.G.S. Bushwood, Wanstead, Essex.
1898. §§KNOCKER, Sir E. WOLLASTON, K.C.B. Castle Hill House, Dover.
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.

Year of Election.

1887. *Knott, Herbert. Aingarth, Stalybridge, Cheshire.
1887. *Knott, John F. Glan-y-Coed, Conway.
1887. ‡Knott, Mrs. Glan-y-Coed, Conway.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1897. ‡Knowlton, W. H. 36 King-street East, Toronto, Canada.
1883. ‡*Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.*
1883. ‡*Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.*
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1892. ‡KOHN, CHARLES A., Ph.D. 20 Mulgrave-street, Liverpool.
1898. ‡Krauss, A. Hawthornden, Priory-road, Tyndall's Park, Clifton, Bristol.
1890. *Krauss, John Samuel, B.A. Hodnet, Salop.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.
1870. ‡Kynaston, Josiah W., F.C.S. 3 Oak-terrace, Beech-street, Liverpool.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec.
1885. *Laing, J. Gerard. 111 Church-street, Chelsea, S.W.
1897. ‡Laird, Professor G. J. Wesley College, Winnipeg, Canada.
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1887. ‡LAMB, HORACE, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. 6 Wilbraham-road, Fallowfield, Manchester.
1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1883. ‡LAMBERT, Rev. BROOKE, LL.B. The Vicarage, Greenwich, S.E.
1896. §Lambert, Frederick Samuel. Balgowan, Newland, Lincoln.
1893. ‡Lambert, J. W., J.P. Lenton Firs, Nottingham.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1893. ‡LAMPLUGH, G. W., F.G.S. Geological Survey Office, Jermyn-street, S.W.
1890. ‡Lamport, Edward Parke. Greenfield Well, Lancaster.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, S.E.
1883. ‡Lang, Rev. Gavin. Mayfield, Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. The University, Aberdeen.
1898. *Lang, William H. 10 Jedburgh-gardens, Kelvinside, Glasgow.
1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Director of the Natural History Museum, Cromwell-road, S.W.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S., Professor of Geology and Physiography in the Mason University College, Birmingham. 28 Duchess-road, Edgbaston, Birmingham.

Year of Election.

1887. ‡Larmor, Alexander. Clare College, Cambridge.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. Longridge, Harrow.
1896. *Last, William J. South Kensington Museum, London, S.W.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1900. §Lauder, Alexander. University College, Bangor.
1870. ‡Laughton, John Knox, M.A., F.R.G.S. 5 Pepy's-road, Wimbledon, Surrey.
1891. ‡Laurie, A. P. Heriot Watt College, Edinburgh.
1892. §Laurie, Malcolm, B.A., B.Sc., F.L.S., Professor of Zoology in St. Mungo's College, Glasgow.
1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, E.C.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia, Canada.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, S.W.
1884. §Law, Robert, F.G.S. Fennyroyd Hall, Hipperholme, near Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1900. §Lawrence, W. Trevor, Ph.D. 57 Prince's Gate, S.W.
1889. §Laws, W. G., M.Inst.C.E. 65 Osborne-road, Newcastle-upon-Tyne.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.
1888. ‡Layard, Miss Nina F. 2 Park-place, Fonnereau-road, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1875. ‡Leach, Colonel Sir G., K.C.B., R.E. 6 Wetherby-gardens, S.W.
1894. *Leahy, A. H., M.A., Professor of Mathematics in Firth College. 92 Ashdell-road, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia, Canada.
1895. *Ledger, Rev. Edmund. Proted, Woods-road, Reigate.
1898. §LEE, ARTHUR, J.P. 10 Berkeley-square, Clifton, Bristol.
1861. ‡*Lee, Henry. Sedgeley Park, Manchester.*
1896. §Lee, Rev. H. J. Barton. 14 Higher Park View, Heavitree, Exeter.
1891. ‡Lee, Mark. The Cedars, Llandaff-road, Cardiff.
1894. *Lee, Mrs. W. Ashdown House, Forest Row, Sussex.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1896. *Leech, Lady. Oak Mount, Timperley, Cheshire.
1892. *LEES, CHARLES H., D.Sc. Osborne, Belgrave-road, Oldham.
1886. *Lees, Lawrence W. Old Ivy House, Tettenhall, Wolverhampton.
1882. ‡*Lees, R. W. Moira-place, Southampton.*
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1896. ‡Lees, William. 10 Norfolk-street, Manchester.
*Leese, Joseph. 3 Lord-street West, Southport.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡LE FEUVRE, J. E. Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW. 18 Bryanston-square, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. ‡Lehfeldt, Robert A. 28 South Molton-street, W.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.

Year of
Election.
1856. ‡LEIGH, The Right Hon. Lord. Stoneleigh Abbey, Kenilworth.
1891. ‡Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1867. ‡*Leishman, James. Gateacre Hall, Liverpool.*
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E., F.G.S. Lansdowne House, Southampton.
1867. ‡Leng, Sir John, M.P. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1887. *Leon, John T. 38 Portland-place, W.
1871. ‡LEONARD, HUGH, M.R.I.A. 24 Mount Merrion-avenue, Blackrock, Co. Dublin.
1874. ‡*Lepper, Charles W. Laurel Lodge, Belfast.*
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1890. *Lester, Joseph Henry. Royal Exchange, Manchester.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1894. ‡Leudesdorf, Charles. Pembroke College, Oxford.
1896. §Lever, W. H. Port Sunlight, Cheshire.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1890. §Levy, J. H. 11 Abbeville-road, Clapham Park, S.W.
1893. *LEWES, VIVIAN B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 54 Highbury-hill, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1899.§§Lewis, Professor E. P. University of California, Berkeley, U.S.A.
1897. §Lewis, Rev. J. Pitt, M.A. Rossin House, Toronto, Canada.
1899.§§Lewis, Thomas. 9 Hubert-terrace, Dover.
1891. ‡*Lewis, W. Lyncombe Villa, Cowbridge-road, Cardiff.*
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1898. §Lippincott, R. C. Cann. Over Court, near Bristol.
1883. ‡Lisle, H. Claud. Nantwich.
1895. *LISTER, The Right Hon. Lord, F.R.C.S., D.C.L., F.R.S. 12 Park-crescent, Portland-place, W.
1888. ‡LISTER, J. J., M.A., F.R.S. Leytonstone, Essex, N.E.
1861. *LIVEING, G. D., M.A., F.R.S., V.P.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *LIVERSIDGE, ARCHIBALD, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry in the University of Sydney, N.S.W.
1880. ‡LLEWELYN, Sir JOHN T. D., Bart., M.P. Penllegare, Swansea.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.
1865. ‡*Lloyd, John. Queen's College, Birmingham.*
1886. ‡Lloyd, J. Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt., F.R.S.E 49A Grove-street, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Park Lane House, Woodgreen, Wednesbury.
1897. §Lloyd-Verney, J. H. 14 Hinde-street, Manchester-square, W.
1854. *LOBLEY, JAMES LOGAN, F.G.S. City of London College, Moorgate-street, E.C.
1892. §Loch, C. S., B.A. 15A Buckingham-street, W.C.

Year of Election.

1867. *Locke, John. 144 St. Olaf's-road, Fulham, S.W.
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡LOCKYER, Sir J. NORMAN, K.C.B., F.R.S. Royal College of Science, South Kensington, S.W.
1900. §Lockyer, W. J. S. 16 Penywern Road, South Kensington, S.W.
1886. *LODGE, ALFRED, M.A., Professor of Pure Mathematics in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. *LODGE, OLIVER J., D.Sc., LL.D., F.R.S., Principal of the University of Birmingham.
1894. *Lodge, Oliver W. F. 225 Hagley Road, Birmingham.
1889. ‡Logan, William. Langley Park, Durham.
1896. §Lomas, J., F.G.S. 13 Moss Grove, Birkenhead.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1876. ‡Long, H. A. Brisbane, Queensland.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1883. ‡Longe, Francis D. Lowestoft.
1898. *Longfield, Miss Gertrude. High Halston Rectory, Rochester.
1883. ‡*Longmaid, William Henry. 4 Rawlinson-road, Southport.*
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1899. *Longstaff, Tom G., B.A., F.R.Met.Soc. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Brown House, Blawith, *viâ* Ulverston.
1861. *Lord, Edward. Adamroyd, Todmorden.
1894. ‡Lord, Edwin C. E., Ph.D. 247 Washington-street, Brooklyn, U.S.A.
1889. ‡Lord, Riley. 75 Pilgrim-street, Newcastle-upon-Tyne.
1897. ‡LOUDON, JAMES, LL.D., President of the University of Toronto, Canada.
1883. *LOUIS, D. A., F.C.S. 77 Shirland-gardens, W.
1896. §Louis, Henry, Professor of Mining, Durham College of Science, Newcastle-on-Tyne.
1887. *LOVE, Professor A. E. H., M.A., F.R.S. 34 St. Margaret's Road, Oxford.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 33 Clanricarde-gardens, W.
1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.
1892. §Lovibond, J. W. Salisbury, Wiltshire.
1889. ‡Low, Charles W. 84 Westbourne-terrace, W.
1867. *Low, James F. Seaview, Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §§Lowdon, John. St. Hilda's, Barry, Glamorgan.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1892. ‡Lowe, D. T. Heriot's Hospital, Edinburgh.
1886. *Lowe, John Landor, B.Sc., M.Inst.C.E. Strathavon, Kedleston Road, Derby.
1894. ‡Lowenthal, Miss Nellie. 60 New North-road, Huddersfield.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Farnborough, R.S.O., Kent.
1881. ‡Lubbock, John B. 14 Berkeley-street, W.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, W.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1878. ‡Lucas, Joseph. Tooting Graveney, S.W.

Year of Election.

1889. ‡Luckley, George. The Grove, Jesmond, Newcastle-upon-Tyne.
1891. *Lucovich, Count A. The Rise, Llandaff.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1897. ‡Lumsden, George E., F.R.A.S. 57 Elm-avenue, Toronto, Canada.
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. ‡Lunn, Robert. Geological Survey Office, Sheriff Court House, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Coal Mining in Yorkshire College, Leeds. 6 De Grey-road, Leeds.
1874. *Lupton, Sydney, M.A. 102 Park Street, Grosvenor Square, W.
1900. §Lupton, William C. Mayor of Bradford.
1864. *Lutley, John. Brockhampton Park, Worcester.
1898. §Luxmoore, Dr. C. M. Reading College, Reading.
1871. ‡Lyell, Sir Leonard, Bart., M.P., F.G.S. 48 Eaton-place, S.W.
1899. §§Lyle, Professor Thomas R. The University, Melbourne.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. ‡Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1896. ‡Lyster, A. G. Dockyard Coburg Dock, Liverpool.
1862. *Lyte, F. Maxwell, M.A., F.C.S. 60 Finborough-road, S.W.

1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.I.C., F.C.S., Professor of Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, Edinburgh.
1876. *Macadam, William Ivison, F.R.S.E., F.I.C., F.C.S. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.A., M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MacAlister, Donald, M.A., M.D., B.Sc. St. John's College, Cambridge.
1896. ‡Macalister, N. A. S. 2 Gordon-street, W.C.
1897. ‡McAllister, Samuel. 99 Wilcox-street, Toronto, Canada.
1896. §Macallum, Professor A. B., Ph.D. 59 St. George Street, Toronto, Canada.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. ‡MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander. 79 Holland-park, W.
1896. ‡McArthur, Charles. Villa Marina, New Brighton, Cheshire.
1884. ‡Macarthur, D. Winnipeg, Canada.
1896. *Macaulay, F. S., M.A. 19 Dewhurst-road, W.
1834. Macaulay, James, A.M., M.D. 4 Wynnstay-gardens, W.
1896. ‡MacBride, Professor E. W., M.A. McGill University, Montreal, Canada.
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.
1887. *McCarthy, James. Bangkok, Siam.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1884. ‡McCausland, Orr. Belfast.
1891. *McClean, Frank, M.A., LL.D., F.R.S., M.Inst.C.E. Rusthall House, Tunbridge Wells.

Year of Election.

1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'CLINTOCK, Admiral Sir FRANCIS L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, S.W.
1872. **McClure, J. H., F.R.G.S. Whiston, Prescot.*
1878. *M'Comas, Henry. Pembroke House, Pembroke Road, Dublin.
1892. *McCowan, John, M.A., D.Sc. Henderson Street, Bridge of Allan, N.B.
1892. ‡McCrae, George. 3 Dick-place, Edinburgh.
1883. ‡*McCrossan, James. 92 Huskisson-street, Liverpool.*
1899.§§McDiarmid, Jabez. The Elms, Stanmore, Middlesex.
1900. §Macdonald, J. R. 3 Lincoln's Inn Fields, W.C.
1890. *MacDonald, Mrs. J. R. 3 Lincoln's Inn Fields, W.C.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, Sir W. C. 891 Sherbrooke-street, Montreal, Canada.
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. ‡*MacDonnell, Rev. Canon J. C., D.D. Misterton Rectory, Lutterworth.*
1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1897. ‡McEwen, William C. 9 South Charlotte-street, Edinburgh.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1897. ‡McFarlane, Murray, M.D. 32 Carlton-street, Toronto, Canada.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1897. ‡McGaw, Thomas. Queen's Hotel, Toronto, Canada.
1888 ‡MacGeorge, James. 67 Marloes-road, Kensington, W.
1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.
1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. Dunavon, Westmount, Montreal, Canada.
1885. ‡*Macgregor, Alexander, M.D. 256 Union-street, Aberdeen.*
1884. *MACGREGOR, JAMES GORDON, M.A., D.Sc., F.R.S., F.R.S.E., Professor of Physics in Dalhousie College, Halifax, Nova Scotia, Canada.
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 26 Buchanan-street, Hillhead, Glasgow.
1867. *MCINTOSH, W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. ‡McIntyre, John, M.D. Odiham, Hants.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1884. §MacKay, A. H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1885. §MACKAY, JOHN YULE, M.D., Professor of Anatomy in University College, Dundee.
1897. ‡McKay, T. W. G., M.D. Oshawa, Ontario, Canada.
1896. *McKechnie, Duncan. Eccleston Grange, Preston.
1873. ‡MCKENDRICK, JOHN G., M.D., LL.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Glasgow. 2 Florentine-gardens, Glasgow.
1883. ‡McKendrick, Mrs. 2 Florentine-gardens, Glasgow.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1884. ‡McKenzie, Stephen, M.D. 26 Finsbury-circus, E.C.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1883. ‡Mackeson, Henry. Hythe, Kent.

Year of Election.

1872. *Mackey, J. A. 175 Grange-road, S.E.
1867. ‡Mackie, Samuel Joseph. 17 Howley-place, W.
1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1887. ‡Mackinder, H. J., M.A., F.R.G.S. Christ Church, Oxford.
1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1891. ‡Mackintosh, A. C. 88 Plymouth Road, Penarth.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1872. *McLachlan, Robert, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1896. ‡Maclagan, Miss Christian. Ravenscroft, Stirling.
1892. ‡Maclagan, Philip R. D. St. Catherine's, Liberton, Midlothian.
1892. ‡Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent, Edinburgh.
1873. ‡McLandsborough, John, F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1885. *M'Laren, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1897. ‡MacLaren, J. F. 380 Victoria-street, Toronto, Canada.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1897. ‡MacLaren, Rev. Wm., D.D. 57 St. George-street, Toronto, Canada.
1892. *Maclean, Magnus, M.A., D.Sc., F.R.S.E., (Local Secretary.) Professor of Electrical Engineering, Technical College, Glasgow.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1868. §McLeod, Herbert, F.R.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1861. *Maclure, Sir John William, Bart., M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMahon, Lieut.-General C. A., F.R.S., F.G.S. 20 Nevern-square, South Kensington, S.W.
1883. ‡MacMahon, Major Percy A., R.A., F.R.S. 52 Shaftesbury-avenue, W.
1878. *M'Master, George, M.A., J.P. Rathmines, Ireland.
1874. ‡*MacMordie, Hans, M.A. 8 Donegall-street, Belfast.*
1884. ‡McMurrick, J. Playfair. University of Michigan, Ann Arbor, Michigan, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, A. W. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
*Macrory, Edmund, M.A. 19 Pembridge-square, W.
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡Maggs, Thomas Charles, F.G.S. 56 Clarendon-villas, West Brighton.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip, B.Sc. 16 Gloucester-terrace, Hyde Park, W.
1896. ‡Maguire, Thomas Philip. Eastfield, Lodge-lane, Liverpool.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1883. ‡Maitland, P. C. 136 Great Portland-street, W.
1899. §§Makarius, Saleem. 'Al Mokattam,' Cairo.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1889. ‡Maling, C. T. 14 Ellison-place, Newcastle-upon-Tyne.

Year of Election.

1857. ‡MALLET, JOHN WILLIAM, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1896. *Manbré, Alexandre. 15 Alexandra-drive, Liverpool.
1897. ‡MANCE, Sir H. C. 32 Earl's Court-square, S.W.
1887. ‡MANCHESTER, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H., M.D. 45 Rodney-street, Liverpool.
1885. ‡*Mann, George. 72 Bon Accord-street, Aberdeen.*
1888. ‡Mann, W. J. Rodney House, Trowbridge.
1894. ‡Manning, Percy, M.A., F.S.A. Watford, Herts.
1864. ‡Mansel-Pleydell, J. C., F.G.S. Whatcombe, Blandford.
1888. ‡MANSERGH, JAMES, M.Inst.C.E., F.G.S. 5 Victoria-street, Westminster, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
1900. §Margerison, Samuel. Calverley Lodge, near Leeds.
1887. ‡Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. ‡Markham, Christopher A., F.R.Met.Soc. Spratton, Northampton.
1864. ‡MARKHAM, Sir CLEMENTS R., K.C.B., F.R.S., Pres.R.G.S., F.S.A. 21 Eccleston-square, S.W.
1894. ‡*Markoff, Dr. Anatolius. 44 Museum-street, W.C.*
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *MARR, J. E., M.A., F.R.S., F.G.S. St. John's College, Cambridge.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1884. *Marsden, Samuel. 1015 North Leffingwell-avenue, St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. 5 Ladywood-road, Roundhay, Leeds.
1887. ‡Marsh, J. E., M.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *MARSHALL, ALFRED, M.A., LL.D., Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1889. ‡*Marshall, Frank, B.A. 31 Grosvenor-place, Newcastle-upon-Tyne.*
1892. §Marshall, Hugh, D.Sc., F.R.S.E. 131 Warrender Park-road, Edinburgh.
1890. ‡Marshall, John. Derwent Island, Keswick.
1881. ‡*Marshall, John Ingham Fearby. 28 St. Saviourgate, York.*
1886. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1849. *MARSHALL, WILLIAM P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1899. §Martin, Miss A. M. Park View, Bayham-road, Seve
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1887. *Martin, Rev. H. A. Grosvenor Club, London, S.W.
1884. §Martin, N. H., J.P., F.L.S. Ravenswood, Low Fell, Gateshead-on-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, New Barnet, Herts.

Year of Election.

1890. §Martindale, William, F.L.S. 19 Devonshire-street, Portland-place, W.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1883. ‡MARWICK, Sir J. D., LL.D., F.R.S.E. (LOCAL SECRETARY.) Glasgow.
1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1873. *MASHAM, Lord. Swinton Park, Swinton.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S. Basset Down House, Swindon.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡*Mason, James, M.D. Montgomery House, Sheffield.*
1896. ‡Mason, Philip B., F.L.S., F.Z.S. Burton-on-Trent.
1893. *Mason, Thomas. Endersleigh, Alexandra Park, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc. University of Melbourne, Victoria, Australia.
1898. ‡Masterman, A. T. University of St. Andrews, N.B.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.P., M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡Mathers, J. S. 1 Hanover-square, Leeds.
1865. ‡Mathews, C. E. Waterloo-street, Birmingham.
1898. ‡Mathews, E. R. Norris. Cotham-road, Cotham, Bristol.
1894. ‡MATHEWS, G. B., M.A., F.R.S. 10 Menai View, Bangor.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, W.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 21 Augustus-road, Edgbaston, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1885. ‡MATTHEWS, JAMES. Springhill, Aberdeen.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1899. §MATTHEWS, WILLIAM, C.M.G., M.Inst.C.E. 9 Victoria-street, S.W.
1893. ‡Mavor, Professor James, M.A., LL.D. University of Toronto, Canada.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
1894. §Maxim, Sir Hiram S. 18 Queen's Gate-place, Kensington, S.W.
1876. ‡*Maxton, John. 6 Belgrave-terrace, Glasgow.*
1887. ‡*Maxwell, James. 29 Princess-street, Manchester.*
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, W.C.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1871. ‡Meikle, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, W.
1887. ‡Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C., Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, W.C.
1867. ‡MELDRUM, CHARLES, C.M.G., LL.D., F.R.S., F.R.A.S. University Hall, Riddle's Court, Edinburgh.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1896. §Mellor, G. H. Weston, Blundell Sands, Liverpool.
1881. §Melrose, James. Clifton Croft, York.
1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.

Year of Election.

1847. ‡*Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.*
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1896. ‡Menneer, R. R. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1862. ‡MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-street, E.C.
1879. ‡MERIVALE, JOHN HERMAN, M.A. Togston Hall, Acklington.
1899. *Merrett, William H. Royal Mint, Tower Hill, E.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1899. §Merryweather, J. C. 4 Whitehall-court, S.W.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1896. §Metzler, W. H., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡MIALL, LOUIS C., F.R.S., F.L.S., F.G.S., Professor of Biology in the Yorkshire College, Leeds.
1886. ‡Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of. Middlesbrough.
1893. §Middleton, A. 25 Lister-gate, Nottingham.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. 46 Windsor-road, Ealing, W.
1894. *MIERS, H. A., M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
1889. ‡Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1886. ‡Miles, Charles Albert. Buenos Ayres.
1881. ‡MILES, MORRIS. Warbourne, Hill-lane, Southampton.
1885. §MILL, HUGH ROBERT, D.Sc., F.R.S.E., F.R.G.S. 22 Gloucester-place, Portman-square, W.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1875. ‡*Miller, George. Brentry, near Bristol.*
1895. ‡Miller, Henry, M.Inst.C.E. Bosmere House, Norwich-road, Ipswich.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John, B.D. The College, Weymouth.
1861. *Miller, Robert. Totteridge House, Hertfordshire, N.
1895. §Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1897. ‡Miller, Willet G., Professor of Geology in Queen's University, Kingston, Ontario, Canada.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in the Glasgow and West of Scotland Technical College, Glasgow. 60 John-street, Glasgow.
1880. ‡Mills, Mansfeldt H., M.Inst.C.E., F.G.S. Sherwood Hall, Mansfield.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *MILNE, JOHN, F.R.S., F.G.S. Shide Hill House, Shide, Isle of Wight.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1898. *Milner, S. Roslington, B.Sc. University College, Sheffield.
1882. ‡Milnes, Alfred, M.A., F.S.S. 22A Goldhurst-terrace, South Hampstead, N.W.
1880. ‡MINCHIN, G. M., M.A., F.R.S., Professor of Mathematics in the Royal Indian Engineering College, Cooper's Hill, Surrey.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.

Year of Election.

1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡*Mitchell, Andrew. 20 Woodside Place, Glasgow.*
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, W.
1885. ‡*Mitchell, Rev. Mitford, B.A. 6 Queen's Terrace, Aberdeen.*
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1895. *Moat, William, M.A. Johnson, Eccleshall, Staffordshire.
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1878. ‡Molloy, Constantine, Q.C. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Right Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1900. §Monckton, H. W., V.P.G.S. 3 Harcourt Buildings, Temple, E.C.
1887. *Mond, Ludwig, Ph.D., F.R.S., F.C.S. 20 Avenue-road, Regent's Park, N.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1882. *Montagu, Sir Samuel, Bart., M.P. 12 Kensington Palace-gardens, W.
1892. ‡Montgomery, Very Rev. J. F. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1896. ‡Moore, A. W., M.A. Woodbourne House, Douglas, Isle of Man.
1894. §Moore, Harold E. 41 Bedford-row, W.C.
1891. ‡*Moore, John. Lindenwood, Park Place, Cardiff.*
1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
1857. **Moore, Rev. William Prior. Carrickmore, Galway, Ireland.*
1896. *Mordey, W. M. Prince's-mansions, Victoria-street, S.W.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1881. ‡Morgan, Alfred. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1895. ‡Morgan, C. Lloyd, F.R.S., F.G.S., Principal of University College, Bristol. 16 Canynge-road, Clifton, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, South Kensington, S.W.
1891. ‡Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1896. §Morgan, George. 61 Hope-street, Liverpool.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1882. §§Morgan, Thomas, J.P. Cross House, Southampton.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1893. ‡Morland, John, J.P. Glastonbury.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 47 Broadhurst-gardens, South Hampstead, N.W.
1889. ‡Morley, The Right Hon. John, M.A., LL.D., M.P., F.R.S. 95 Elm Park-gardens, S.W.
1896. ‡Morrell, R. S. Caius College, Cambridge.
1881. ‡Morrell, W. W. York City and County Bank, York.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. ‡Morris, Daniel, C.M.G., M.A., D.Sc., F.L.S. Barbados, West Indies.
1899. §Morris, G. Harris, Ph.D., F.I.C. 18 Gwendwr-road, West Kensington, W.

Year of
Election.

1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡*Morris, John. 4 The Elms, Liverpool.*
1896. *Morris, J. T. 13 Somers-place, W.
1888. ‡Morris, J. W., F.L.S. 27 Green Park, Bath.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1874. §§Morrison, G. J., M.Inst.C.E. Shanghai, China.
1899. §Morrow, Captain John, M.Sc. 7 Rockleaze-avenue, Sneyd Park, Bristol.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1858. *MORTON, HENRY JOSEPH. 2 Westbourne-villas, Scarborough.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. Hockliffe Grange, Leighton Buzzard.
1896. *Morton, William B., M.A., Professor of Natural Philosophy in Queen's College, Belfast.
1883. ‡Moseley, Mrs. Firwood, Clevedon, Somerset.
1878. *Moss, JOHN FRANCIS, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1876. §Moss, RICHARD JACKSON, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. 5 Chiswick-place, Eastbourne.
1892. ‡Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.
1873. ‡Mossman, William. St. Hilda's, Frizinghall, Bradford.
1892. *Mostyn, S. G., M.A. 19 Peak-hill, Sydenham, S.E.
1866. ‡MOTT, FREDERICK T., F.R.G.S. Crescent House, Leicester.
1856. ‡Mould, Rev. J. G., B.D. Roseland, Meadfoot, Torquay.
1878. *MOULTON, J. FLETCHER, M.A., Q.C., M.P., F.R.S. 57 Onslow-square, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1861. *Mountcastle, William Robert. The Wigwam, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount Edgcumbe, Devonport.
1899. §Mowll, Martyn. Chaldercot, Leyburne-road, Dover.
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., M.A., F.C.S. Heightley, Chudleigh, Devon.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1899. *Muff, Herbert B. Aston Mount, Heaton, Bradford, Yorkshire.
1894. ‡Mugliston, Rev. J., M.A. Newick House, Cheltenham.
1876. *Muir, Sir John, Bart. Demster House, Perthshire.
1874. ‡MUIR, M. M. PATTISON, M.A. Gonville and Caius College, Cambridge.
1872. *Muirhead, Alexander, D.Sc., F.C.S. 2 Prince's-street, Storey's-gate, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. 24 Kersland-street, Hillhead, Glasgow.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
1897. ‡Mullins, W. E. Preshute House, Marlborough, Wilts.
1898. §§Mumford, C. E. Bury St. Edmunds.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, E.C.
1876. ‡Munro, Donald, M.D., F.C.S. The University, Glasgow.

Year of Election.

1898. ‡Munro, John, Professor of Mechanical Engineering in the Merchant Venturers' Technical College, Bristol.
1883. *MUNRO, ROBERT, M.A., M.D. 48 Manor-place, Edinburgh.
1855. ‡Murdoch, James Barclay. Capelrig, Mearns, Renfrewshire.
1890. ‡Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1884. §Murphy, Patrick. Marcus-square, Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1891. ‡MURRAY, G. R. M., F.R.S., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, S.W.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡MURRAY, Sir JOHN, K.C.B., LL.D., Ph.D., F.R.S., F.R.S.E. Challenger Lodge, Wardie, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 9 Ellison-place, Newcastle-on-Tyne.
1874. §Musgrave, Sir James, Bart., J.P. Drumglass House, Belfast.
1897. ‡Musgrave, James, M.D. 511 Bloor-street West, Toronto, Canada.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1891. ‡Muybridge, Eadweard. University of Pennsylvania, Philadelphia, U.S.A.
1890. *MYRES, JOHN L., M.A., F.S.A. Christ Church, Oxford.

1886. ‡NAGEL, D. H., M.A. Trinity College, Oxford.
1892. *Nairn, Michael B. Kirkaldy, N.B.
1890. §Nalder, Francis Henry. 34 Queen-street, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡NARES, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 11 Claremont-road, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D. Troy, New York, U.S.A.
1896. ‡Neal, James E., U.S. Consul. 26 Chapel-street, Liverpool.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore, B.A. The Vista, Leominster.
1887. ‡*Neill, Joseph S. Claremont, Broughton Park, Manchester.*
1887. ‡Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1897. ‡Nesbitt, Beattie S. A., M.D. 71 Grosvenor-street, Toronto, Canada.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1898. §Nevill, Rev. J. H. N., M.A. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡NEVILLE, F. H., M.A., F.R.S. Sidney College, Cambridge.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1889. *Newall, H. Frank. Madingley Rise, Cambridge.
1886. ‡Newbolt, F. G. Oakley Lodge, Weybridge, Surrey.
1889. §Newstead, A. H. L., B.A. Rose Villa, Prospect-road, Woodford Green.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1892. ‡NEWTON, E. T., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.

Year of Election.

1867. ‡Nicholl, Thomas. Dundee.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1887. *Nicholson, John Carr. Moorfield House, Headingley, Leeds.
1884. ‡NICHOLSON, JOSEPH S., M.A., D.Sc., Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. ‡Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1893. ‡Nickolls, John B., F.C.S. The Laboratory, Guernsey.
1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1901. §NICOL, JAMES (LOCAL TREASURER), City Chamberlain. Glasgow.
1885. ‡Nicol, W. W. J., D.Sc., F.R.S.E. 15 Blacket-place, Edinburgh.
1896. ‡Nisbet, J. Tawse. 175 Lodge-lane, Liverpool.
1878. ‡NIVEN, CHARLES, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Old Aberdeen.
1877. ‡Niven, Professor James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1863. *NOBLE, Sir ANDREW, K.C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
1879. ‡Noble, T. S. Lendal, York.
1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1888. ‡Norman, George. 12 Brock-street, Bath.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Dale House, Coalbrookdale, R.S.O., Shropshire.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. 98 Anglesea-road, Ipswich.
Nowell, John. Farnley Wood, near Huddersfield.
1896. ‡Nugent, the Right Rev. Monsignor. 18 Adelaide-terrace, Waterloo, Liverpool.
1887. ‡*Nursey, Perry Fairfax. 2 Trafalgar-buildings, Northumberland-avenue, London, W.C.*

1898. *O'Brien, Neville Forth. Queen Anne's-mansions, S.W.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, E.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1894. §Ogden, James. Kilner Deyne, Rochdale.
1896. ‡Ogden, Thomas. 4 Prince's-avenue, Liverpool.
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡OGILVIE, F. GRANT, M.A., B.Sc., F.R.S.E. Heriot Watt College, Edinburgh.

Year of
Election.

1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Derby.
1884. ‡O'Halloran, J. S., C.M.G. Royal Colonial Institute, Northumberland-avenue, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1887. ‡*Oldham, Charles. Romiley, Cheshire.*
1896. ‡Oldham, G. S. Town Hall, Birkenhead.
1892. ‡Oldham, H. Yule, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1853. ‡OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.
1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1893. *Oldham, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., Cornhill, E.C.
1892. ‡*Oliphant, James. 50 Palmerston-place, Edinburgh.*
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡OLIVER, F. W., D.Sc., F.L.S., Professor of Botany in University College, London. The Tower House, Tite-street, Chelsea, S.W.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. §Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.L.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1860. *OMMANNEY, Admiral Sir ERASMUS, C.B., LL.D., F.R.S., F.R.A.S., F.R.G.S. 29 Connaught-square, Hyde Park, W.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1872. ‡Onslow, D. Robert. New University Club, St. James's, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit in the University of Berlin.
1867. ‡*Orchar, James G. 9 William-street, Forebank, Dundee.*
1883. ‡*Ord, Miss Maria. Fern Lea, Park-crescent, Southport.*
1899. §§Orling, Axel. Moorgate Station-chambers, E.C.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡*Orpen, Miss. 58 Stephen's-green, Dublin.*
1884. *Orpen, Lieut.-Colonel R. T., R.E. Care of G. H. Orpen, Esq., Erpingham, Bedford Park, Chiswick.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1899. §§Osborn, Dr. F. A. The Châlet, Dover.
1897. ‡Osborne, James K. 40 St. Joseph-street, Toronto, Canada.
1887. §O'Shea, L. T., B.Sc. University College, Sheffield.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1897. ‡Osler, E. B., M.P. Rosedale, Toronto, Canada.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡OSLER, Professor WILLIAM, M.D., F.R.S. Johns Hopkins University, Baltimore, U.S.A.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 14 Mill Hill-road, Derby.
1896. ‡Oulton, W. Hillside, Gateacre, Liverpool.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1896. §Owen, Peter. The Elms, Capenhurst, Chester, and 2 Dale Street, Liverpool.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.

Year of
Election.

1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1894. ‡Paget, Octavius. 158 Fenchurch-street, E.C.
1898. §§Paget, The Right Hon. Sir R. H., Bart. Cranmore Hall, Shepton Mallet.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D. Stroud, Gloucestershire.
1870. *PALGRAVE, ROBERT HARRY INGLIS, F.R.S., F.S.S. Belton, Great Yarmouth.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1872. *Palmer, W. R. 49 Tierney-road, Streatham Hill, S.W.
1883. ‡*Pant, F. J. Van der. Clifton Lodge, Ringston-on-Thames.*
1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1898. ‡Parker, G., M.D. 14 Pembroke-road, Clifton, Bristol.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1899. §§Parker, Mark. 30 Upper Fant-road, Maidstone.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1899. *Parkin, John. Blaithwaite, Carlisle.
1879. ‡Parkin, William. The Mount, Sheffield.
1887. §§Parkinson, James. Greystones, Langho, Blackburn.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1878. ‡PARSONS, Hon. C. A., F.R.S., M.Inst.C.E. Holeyn Hall, Wylam-on-Tyne.
1883. ‡*Part, Isabella. Rudleth, Watford, Herts.*
1898. *Partridge, Miss Josephine M. Girton College, Cambridge.
1898. ‡Pass, Alfred C. Clifton Down, Bristol.
1881. ‡Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in University College, Liverpool.
1897. ‡Paterson, John A. 23 Walmer-road, Toronto, Canada.
1896. ‡Paton, A. A. Greenbank-drive, Wavertree, Liverpool.
1897. ‡PATON, D. NOËL, M.D. 33 George-square, Edinburgh.
1883. *Paton, Rev. Henry, M.A. 120 Polwarth Terrace, Edinburgh.
1884. *Paton, Hugh. Box 2400, Montreal, Canada.
1871. **Patterson, A. Henry.* 16 *Ashburn-place, S.W.*
1876. ‡Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡PATTINSON, JOHN, F.C.S. 75 The Sidë, Newcastle-upon-Tyne.
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
1863. ‡*Paul, Benjamin H., Ph.D.* 1 *Victoria-street, Westminster, S.W.*
1883. ‡Paul, George. 10 St. Mary's Avenue, Harrogate.
1892. ‡Paul, J. Balfour. 30 Heriot-row, Edinburgh.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S. 35 Grosvenor-street, W.
1887. *Paxman, James. Stisted Hall, near Braintree, Essex.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.

Year of Election.

1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles. 1 Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. 1 Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Joseph F., M.D. 78 Wimpole-street, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Wellington-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡Peach, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, W.C.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, N.W.
1883. ‡Pearson, Arthur A. Colonial Office, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Chilwell House, Nottinghamshire.
1898. §Pearson, George. Bank Chambers, Baldwin-street, Bristol.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. **Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.*
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
1881. ‡Pearson, Richard. 57 Bootham, York.
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-upon-Tyne.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
*Peckover, Alexander, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, D.Sc., F.R.S.E. 2 Cameron-park, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡Peek, Sir Cuthbert E., Bart., M.A., F.S.A. 22 Belgrave-square, S.W.
1878. *Peek, William. The Manor House, Kemp Town, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, S.W.
1861. *Peile, George. Greenwood, Shotley Bridge, Co. Durham.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, W.C.
1887. §Pendlebury William H., M.A., F.C.S. 6 Gladstone-terrace, Priory Hill, Dover.
1894. §Pengelly, Miss. Lamorna, Torquay.
1894. §Pengelly, Miss Hester. Lamorna, Torquay.
1897. ‡Penhallow, Professor D. P., M.A. McGill University, Montreal, Canada.
1896. ‡Pennant, P. P. Nantlys, St. Asaph.
1898. ‡Pentecost, Harold, B.A. Clifton College, Bristol.
1881. ‡*Penty, W. G. Melbourne-street, York.*
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1889. ‡Percival, Archibald Stanley, M.A., M.B. 16 Ellison-place, Newcastle-upon-Tyne.
1898. ‡Percival, Francis W., M.A., F.R.G.S. 2 Southwick-place, W.
1895. §§Percival, John, M.A., Professor of Botany in the South-Eastern Agricultural College, Wye, Kent.
*Perigal, Frederick. Lower Kingswood, Reigate.
1894. §Perkin, A. G., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Hyde Park, Leeds.

Year of Election.

1868. *PERKIN, WILLIAM HENRY, Ph.D., LL.D., F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡PERKIN, WILLIAM HENRY, jun., LL.D., Ph.D., F.R.S., F.C.S., Professor of Organic Chemistry in Owens College, Manchester. Fairview, Wilbraham Road, Fallowfield, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1898. *Perman, E. P. University College, Cardiff.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, N.W.
1886. ‡Perrin, Mrs. 31 St. John's Wood Park, N.W.
1874. *PERRY, JOHN, M.E., D.Sc., F.R.S., Professor of Mechanics and Mathematics in the Royal College of Science, S.W.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1900. §Petavel, G. E. 34 Abingdon Mansions, Kensington, W.
1897. ‡Peters, Dr. George A. 171 College-street, Toronto, Canada.
1898. ‡Pethick, William. Woodside, Stoke Bishop, Bristol.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1895. §§PETRIE, W. M. FLINDERS, D.C.L., Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth-avenue, Hove, Brighton.
1886. ‡Phelps, Major-General A. 23 Augustus-road, Edgbaston, Birmingham.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, S.W.
1896. §§Philip, George, jun. Weldon, Bidston, Cheshire.
1892. ‡Philip, R. W., M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Elizabeth Lodge, George-lane, Woodford, Essex.
1863. ‡Philipson, Sir G. H. 7 Eldon-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1899. §Phillips, Charles E. S. Castle House, Shooter's Hill, Kent.
1894. §Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1887. ‡Phillips, H. Harcourt, F.C.S. 183 Moss-lane East, Manchester.
1890. §Phillips, R. W., M.A., D.Sc., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1898. ‡Philps, Captain Lambe. 7 Royal-terrace, Weston-super-Mare.
1884. *Pickard, Rev. H. Adair, M.A. Airedale, Oxford.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1894. ‡PICKARD-CAMBRIDGE, Rev. O., M.A., F.R.S. Bloxworth Rectory, Wareham.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.
1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A.
1896. ‡Picton, W. H. College-avenue, Crosby, Liverpool.
1888. *Pidgeon, W. R. 42 Porchester-square, W.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 12 King's Bench-walk, Temple, E.C.
1865. ‡PIKE, L. OWEN. 4A Marlborough-gate, Hyde Park, W.
1873. ‡Pike, W. H., M.A., Ph.D. Toronto, Canada.
1896. *Pilkington, A. C. The Hazels, Prescot, Lancashire.
1896. *Pilling, William. Rosario, Heene-road, West Worthing.

Year of Election.

1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡Pitt, George Newton, M.A., M.D. 24 St. Thomas-street, Borough, S.E.
1864. ‡*Pitt, R. 5 Widcomb-terrace, Bath.*
1883. ‡Pitt, Sydney. 16 St. Andrew's-street, Holborn-circus, E.C.
1893. *PITT, WALTER, M.Inst.C.E. South Stoke House, near Bath.
1900. *Platts, Walter. Fairmount, Bingley.
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 38 Grosvenor-street, W.
1898. §§Playne, H. C. 28 College-road, Clifton, Bristol.
1893. ‡Plowright, Henry J. Brampton Foundries, Chesterfield.
1897. ‡Plummer, J. H. Bank of Commerce, Toronto, Canada.
1898. §Plummer, W. E. The Observatory, Bidston, Birkenhead.
1899. §§Plumptre, Fitzwalter. Goodnestone, Dover.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Queen's Co., Ireland.
1900. *Pocklington, H. Cabourn. 41 Virginia Road, Leeds.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡Pocock, Rev. Francis. 4 Brunswick-place, Bath.
1896. ‡Pollard, James. High Down, Hitchin, Herts.
1898. §§POLLEN, Rev. G. C. H., F.G.S. Ancienne Abbaye, Tronchiennes, Ghent, Belgium.
1896. *Pollex, Albert. Dale End, Cavendish Park, Rockferry.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1900. §Pope, W. J. 5 Hillingdon Mansions, Elephant and Castle, S.E.
1892. §Popplewell, W. C., M.Sc., Assoc.M.Inst.C.E. Yorkshire College, Leeds.
1868. ‡PORTAL, Sir WYNDHAM S. Bart. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D., D.D. All Saints' Vicarage, Southport.
1883. ‡Postgate, Professor J. P., M.A. University College, Gower Street, W.C.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Highbury, Newcastle-upon-Tyne.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S., Professor of Zoology in the University of Oxford. Wykeham House, Banbury-road, Oxford.
1898. *Poulton, Edward Palmer. Wykeham House, Banbury-road, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Brynmill-crescent, Swansea.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole Street, Cavendish Square, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, St. Ann-street, Manchester.

Year of
Election.

1867. ‡Powrie, James. Reswallie, Forfar.
1883. ‡POYNTING, J. H., D.Sc., F.R.S., Professor of Physics in the Mason University College, Birmingham.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1869. *PREECE, Sir WILLIAM HENRY, K.C.B., F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey; and 13 Queen Anne's Gate, S.W.
1888. *Preece, W. Llewellyn. Tan-y-bryn, Rusholme-road, Putney Heath, S.W.
1892. §Prentice, Thomas. Willow Park, Greenock.
1889. §Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1894. ‡Preston, Arthur E. Piccadilly, Abingdon, Berkshire.
1893. *Preston, Martin Inett. 48 Ropewalk, Nottingham.
1884. *Prevost, Major L. de T., 2nd Battalion Argyll and Sutherland Highlanders.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. ‡Price, William. 40 Park-place, Cardiff.
1897. *Price, W. A., M.A. 11 Waterloo Square, Bognor.
1897. ‡Primrose, Dr. Alexander. 196 Simcoe-street, Toronto, Canada.
1892. ‡Prince, Professor Edward E., B.A. Ottawa, Canada.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, N.W.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 70 Fairhazel Gardens, South Hampstead, N.W.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1888. ‡Probyn, Leslie C. Onslow-square, S.W.
1881. §Procter, John William. Ashcroft, York.
1863. ‡Proctor, R. S. Grey-street, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1884. *Proudfoot, Alexander, M.D. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Slade-road, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1871. *Puckle, Rev. T. J. Chestnut House, Huntingdon-road, Cambridge.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1899. §§Pullar, Frederick P. The Lea, Bridge of Allan, N.B.
1867. *Pullar, Sir Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1842. *Pumphrey, Charles. Castlewood, Park-road, Moseley, Birmingham.
1887. §PUMPHREY, WILLIAM. 2 Oakland-road, Redland, Bristol.
1885. ‡PURDIE, THOMAS, B.Sc., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stratford-place, Oxford-street, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. Willesley, Park Hill Rise, Croydon.
1883. §Pye-Smith, Mrs. Willesley, Park Hill Rise, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, S.E.

Year of Election.

1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.

1896. ‡Quaill, Edward. 3 Palm-grove, Claughton.
1893. ‡Quick, James. University College, Bristol.
1894. ‡Quick, Professor W. J. University of Missouri, Columbia, U.S.A.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, S.W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1896. §Radcliffe, Herbert. Balderstone Hall, Rochdale.
1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1887. *Ragdale, John Rowland. The Beeches, Strand, near Manchester.
1864. ‡Rainey, James T. 3 Kent-gardens, Ealing, W.
1898. *Raisin, Miss Catherine A., D.Sc. Bedford College, York-place, Baker-street, W.
1896. *Ramage, Hugh. St. John's College, Cambridge.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.S., F.R.A.S., M.R.I.A. Radcliffe Observatory, Oxford.
1863. ‡RAMSAY, ALEXANDER. 2 Cowper-road, Acton, Middlesex, W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John. Kildalton, Argyllshire.
1885. ‡Ramsay, Major. Straloch, N.B.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1876. *RAMSAY, WILLIAM, Ph.D., F.R.S., Professor of Chemistry in University College, London. 12 Arundel-gardens, W.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, W.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1893. ‡Ransom, W. B., M.D. The Pavement, Nottingham.
1863. ‡RANSOM, WILLIAM HENRY, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡RANSOME, ARTHUR, M.A., M.D., F.R.S. Sunnyhurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, N.W.
1864. ‡Rate, Rev. John, M.A. Fairfield, East Twickenham.
1892. *Rathbone, Miss May. Backwood, Neston, Cheshire.
1870. §Rathbone, R. R. Glan y Menai, Anglesey.
1895. ‡RATHBONE, W., LL.D. Green Bank, Liverpool.
1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. 2 York-mansions, Battersea Park, S.W.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1886. ‡Rawson, W. Stepney, M.A. 68 Cornwall-gardens, Queen's-gate, S.W.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Natural Philosophy in the Royal Institution. Terling Place, Witham, Essex.
1895. ‡Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.

Year of Election.

1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree. Teviot Dale, Stockport.
1896. *READ, CHARLES H., F.S.A. British Museum, W.C.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1899. §§Reaster, James William. 68 Linden-grove, Nunhead, S.E.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1892. ‡Redgrave, Gilbert R., Assoc.Inst.C.E. The Elms, Westgate-road, Beckenham, Kent.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1890. *Redwood, Boverton, F.R.S.E., F.C.S. Glen Wathen, Church End, Finchley, N.
1861. ‡REED, Sir EDWARD JAMES, K.C.B., F.R.S. Broadway-chambers, Westminster, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill, Carlisle.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. 15 Merridale-lane, Wolverhampton.
1891. *Rees, I. Treharne, M.Inst.C.E. Highfield, Penarth.
1888. ‡Rees, W. L. 11 North-crescent, Bedford-square, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1897. ‡Reeve, Richard A. 22 Shuter-street, Toronto, Canada.
1881. §Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.R.S., F.L.S., F.G.S. 28 Jermyn-street, S.W.
1892. ‡REID, E. WAYMOUTH, B.A., F.R.S., Professor of Physiology in University College, Dundee.
1889. ‡Reid, G., Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1897. §Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892. ‡Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1893. ‡Reinach, Baron Albert von. Frankfort s. M., Prussia.
1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physics in the Royal Naval College, Greenwich, S.E.
1863. ‡RENALS, E. 'Nottingham Express' Office, Nottingham.
1894. ‡RENDALL, Rev. G. H., M.A. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. Bank House, 135 Lord-street, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1900. *Reynolds, Miss K. M. 4 Colinette Road, Putney, S.W.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in Owens College, Manchester. 19 Lady Barn-road, Fallowfield, Manchester.
1896. ‡Reynolds, Richard S. 73 Smithdown-lane, Liverpool.
1896. §Rhodes, Albert. Fieldhurst, Liversidge, Yorkshire.
1858. *Rhodes, John. Potternewton House, Chapel Allerton, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1888. ‡*Rhodes, John George. Warwick House, 46 St. George's-road, S.W.*
1890. ‡Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.

Year of Election.

1899. *RHYS, Professor JOHN, M.A. Jesus College, Oxford.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro, 14, Modena, Italy.
1891. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888. *RICHARDSON, ARTHUR, M.D.
1869. *Richardson, Charles. 6 The Avenue, Bedford Park, Chiswick.
1882. §Richardson, Rev. George, M.A. Walcote, Winchester.
1884. *Richardson, George Straker. Isthmian Club, Piccadilly, W.
1889. ‡Richardson, Hugh., M.A. Bootham School, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. Montevideo, Chickerell, near Weymouth.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1881. ‡*Richardson, W. B. Elm Bank, York.*
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.
1891. §Riches, T. Harry. 8 Park-grove, Cardiff.
1886.§§Richmond, Robert. Heathwood, Leighton Buzzard.
1868. ‡RICKETTS, CHARLES, M.D., F.G.S. 19 Hamilton-square, Birkenhead.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-street, S.W.
1894. §RIDLEY, E. P. Burwood, Westerfield Road, Ipswich.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, N.W.
1889. ‡Ridley, Thomas D. Coatham, Redcar.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1881. *Rigg, Arthur. 15 Westbourne Park Villas, W.
1883. *RIGG, EDWARD, M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*RIPON, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, S.W.
1892. ‡Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.
1867. ‡*Ritchie, William. Emslea, Dundee.*
1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.
1900. §Rixon, F. W., B.Sc. 79 Green Lane, Heywood, Lancashire.
1898. §Robb, Alfred A. Lisnabreeny House, Belfast.
1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1887. *Roberts, Evan. 30 St. George's-square, Regent's Park, N.W.
1859. ‡Roberts, George Christopher. Hull.
1870. *ROBERTS, ISAAC, D.Sc., F.R.S., F.R.A.S., F.G.S. Starfield, Crowborough, Sussex.
1894. *Roberts, Miss Janora. 14 Alexandra Road, Southport.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 17 Charterhouse-square, E.C.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1896. §Roberts, Thomas J. 33 Serpentine-road, Egremont, Cheshire.
1868. *ROBERTS-AUSTEN, Sir W. CHANDLER, K.C.B., D.C.L., F.R.S., V.P.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London. (GENERAL SECRETARY.) Royal Mint, E.
1883. ‡Robertson, Alexander. Montreal, Canada.

Year of
Election.

1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1883. ‡Robertson, George H. Plas Newydd, Llangollen.
1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.
1897. §ROBERTSON, Sir GEORGE S., K.C.S.I. 1 Pump Court, Temple, E.C.
1897. §Robertson, Professor J. W. Department of Agriculture, Ottawa, Canada.
1892. ‡Robertson, W. W. 3 Parliament-square, Edinburgh.
1888. **Robins, Edward Cookworthy, F.S.A. 8 Marlborough-road, St. John's Wood, N.W.*
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1898. §Robinson, Charles E., M.Inst.C.E. Selborne, Ashburton, South Devon.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1897. ‡Robinson, Haynes. St. Giles's Plain, Norwich.
1887. §Robinson, Henry, M.Inst.C.E. 13 Victoria-street, S.W.
1888. ‡Robinson, John. 8 Vicarage-terrace, Kendal.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1899. *Robinson, Mark, M.Inst.C.E. Overslade, Bilton, near Rugby.
1887. §§Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, S.W.
1875. *Robinson, Robert, M.Inst.C.E. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1891. ‡Robinson, William, Assoc.M.Inst.C.E., Professor of Engineering in University College, Nottingham.
1888. ‡Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, N.W.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
1890. ‡Rochester, The Right Rev. E. S. Talbot, D.D., Lord Bishop of. Kennington Park, S.E.
1896. §§Rock, W. H. 73 Park-road East, Birkenhead.
1896. ‡Rodger, Alexander M. The Museum, Tay Street, Perth.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. New Adelphi Chambers, 6 Robert Street, Adelphi, W.C.
1866. ‡Roe, Sir Thomas. Grove-villas, Litchurch.
1898. ‡ROGERS, BERTRAM, M.D. 11 York-place, Clifton, Bristol.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1890. *Rogers, L. J., M.A., Professor of Mathematics in Yorkshire College, Leeds. 13 Beech Grove-terrace, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Canon Saltren, M.A. Tresleigh, St. Austell, Cornwall.
1884. *Rogers, Walter. Hill House, St. Leonards.
1889. ‡Rogerson, John. Croxdale Hall, Durham.
1897. ‡Rogerson, John. Barrie, Ontario, Canada.
1876. ‡ROLLIT, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1892. *Romanes, John. 3 Oswald-road, Edinburgh.
1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1894. *Rooper, T. Godolphin. 12 Cumberland-place, Southampton.
1881. *Roper, W. O. Bank-buildings, Lancaster.
1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., F.R.S. 10 Bramham-gardens, S.W.

Year of Election.

1883. *Rose, J. Holland, M.A. 11 Endlesham-road, Balham, S.W.
1894. *Rose, T. K., D.Sc. 9 Royal Mint, E.
1900. §Rosenhain, Walter, B.A. St. John's College, Cambridge.
1885. ‡Ross, Alexander. Riverfield, Inverness.
1887. ‡Ross, Edward. Marple, Cheshire.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1869. *Rosse, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1891. §Roth, H. Ling. 32 Prescot-street, Halifax, Yorkshire.
1893. ‡Rothera, G. B. Sherwood Rise, Nottingham.
1865. *Rothera, George Bell. Hazlewood, Forest Grove, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
1884. *Rouse, M. L. Hollybank, Hayne Road, Beckenham.
1861. ‡Routh, Edward J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1881. ‡*Rowe, Rev. G. Lord Mayor's Walk, York.*
1865. ‡Rowe, Rev. John. 13 Hampton-road, Forest Gate, Essex.
1877. ‡Rowe, J. Brooking, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1890. ‡Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.
1881. *Rowntree, John S. Mount Villas, York.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1899.§§Rubie, G. S. Belgrave House, Folkestone-road, Dover.
1875. *Rücker, A. W., M.A., D.Sc., Sec.R.S., Professor of Physics in the Royal College of Science, London. (President-elect.) 19 Gledhow-gardens, South Kensington, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonards-on-Sea.
1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 1 Victoria Villas, Brondesbury, N.W.
1896. *Rundell, T. W., F.R.Met.Soc. 25 Castle-street, Liverpool.
1887. ‡Ruscoe, John. Ferndale, Gee Cross, near Manchester.
1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
1884. ‡Russell, George. 13 Church-road, Upper Norwood, S.E.
Russell, John. 39 Mountjoy-square, Dublin.
1890. ‡Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 16 Bardwell-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, W.
1876. ‡Russell, Robert, F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.
1852. *Russell, William J., Ph.D., F.R.S., F.C.S. 34 Upper Hamilton-terrace, St. John's Wood, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1897. ‡Rutherford, A. Toronto, Canada.
1891.§§Rutherford, George. Dulwich House, Pencisely-road, Cardiff.
1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
1879. ‡*Ruxton, Vice-Admiral, Fitzherbert R.N. 41 Cromwell-gardens, S.W.*
1875. ‡*Ryalls, Charles Wagner, LL.D. 3 Brick-court, Temple, E.C.*
1889. ‡Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.

Year of
Election.

1897. ‡Ryerson, G. S., M.D. Toronto, Canada.
1898. §Ryland, C. J. Southerndon House, Clifton, Bristol.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. 186 Aldersgate-street, E.C.
1886. ‡*St. Clair, George, F.G.S. 225 Castle Road, Cardiff.*
1893. ‡SALISBURY, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S. 20 Arlington Street, S.W.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., LL.D., F.R.S., Provost o Trinity College, Dublin.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1894. ‡SAMUELSON, The Right Hon. Sir BERNHARD, Bart., F.R.S., M.Inst.C.E. 56 Prince's-gate, S.W.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, S.W.
1893. ‡Sanderson, F. W., M.A. The School, Oundle.
1872. §SANDERSON, Sir J. S. BURDON, Bart., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E., Regius Professor of Medicine in the University of Oxford. 64 Banbury-road, Oxford.
1883. ‡Sanderson, Lady Burdon. 64 Banbury-road, Oxford.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, Assoc.M.Inst.C.E. Highfield, Northwich.
1896. ‡Saner, Mrs. Highfield, Northwich.
1892. §Sang, William D. Tylehurst, Kirkcaldy, Fife.
1886. §Sankey, Percy E. 44 Russell Square, W.C.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1896. ‡Sargant, W. L. Quarry Hill, Reigate.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund street, Birmingham.
1900. *Saunder, S. A. Fir Holt, Crowthorne, Berks.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W., F.R.G.S. 3 Elmfield on the Knowles Newton Abbot, Devon.
1884. ‡SAUNDERS, Dr. WILLIAM. Experimental Farm, Ottawa, Canada.
1891. ‡Saunders, W. H. R. Llanishen, Cardiff.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1887.§§Savage, Rev. Canon E. B., M.A., F.S.A. St. Thomas' Vicarage, Douglas, Isle of Man.
1871. ‡Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1887. §SAYCE, Rev. A. H., M.A., D.D., Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1879. *SCHÄFER, E. A., LL.D., F.R.S., M.R.C.S., Professor of Physiology in the University of Edinburgh.

Year of Election.

1888. *SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1892. ‡Schloss, David F. 1 Knaresborough-place, S.W.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1887. ‡Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1885. §Scholes, L. Ivy Dene, Oak-road, Sale, Cheshire.
SCHUNCK, EDWARD, Ph.D., F.R.S., F.C.S. Oaklands, Kersal Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Owens College, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. 3 Hanover-square, W.
1883. *SCLATER, W. LUTLEY, M.A., F.Z.S. South African Museum, Cape Town.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *SCOTT, ALEXANDER, M.A., D.Sc., F.R.S. Royal Institution, Albemarle-street, W.
1878. *Scott, Arthur William, M.A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. ‡Scott, Miss Charlotte Angas, D.Sc. Bryn Mawr College, Pennsylvania, U.S.A.
1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., F.L.S. (GENERAL SECRETARY.) The Old Palace, Richmond, Surrey.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.
1897. ‡Scott, James. 173 Jameson-avenue, Toronto, Canada.
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.R.Met.S. 6 Elm Park-gardens, S.W.
1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.
1895. ‡Scott-Elliot, G. F., M.A., B.Sc., F.L.S Newton, Dumfries.
1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1895. §Scull, Miss E. M. L. The Pines, 10 Langland-gardens, Hampstead, N.W.
1890. §Searle, G. F. C., M.A. Peterhouse, Cambridge.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡SEDGWICK, ADAM, M.A., F.R.S. Trinity College and 4 Craven-road, Cambridge.
1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geology in King's College, London. 25 Palace Gardens-terrace, Kensington, W.
1891. ‡Selby, Arthur L., M.A., Assistant Professor of Physics in University College, Cardiff.
1893. ‡SELBY-BIGGE, L. A., M.A. Charity Commission, Whitehall, S.W.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. ‡Selim, Adolphus. 21 Mincing-lane, E.C.
1897. ‡Selous, F. C., F.R.G.S. Alpine Lodge, Worplesden, Surrey.
1884. ‡SELWYN, A. R. C., C.M.G., F.R.S., F.G.S. Ottawa, Canada.
1885. ‡Semple, Dr. A. United Service Club, Edinburgh.
1888. *SENIER, ALFRED, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1888. *Sennett, Alfred R., A.M.Inst.C.E. The Chalet, Portinscale-road, Putney, S.W.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1892. ‡Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.

Year of Election.

1895. *Seton-Karr, H. W. 31 Lingfield Road, Wimbledon, Surrey.
1892. §SEWARD, A. C., M.A., F.R.S., F.G.S. Westfield, Huntingdon-road, Cambridge.
1891. ‡Seward, Edwin. 55 Newport-road, Cardiff.
1868. ‡Sewell, Philip E. Catton, Norwich.
1899. §Seymour, Henry, J. 16 Wellington-road, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1888. ‡Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 30 St. Charles-square, Ladbroke Grove-road, W.
1871. *Shand, James. Parkholme, Elm Park-gardens, S.W.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1878. ‡SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1896. ‡Sharp, Mrs. E. 65 Sankey-street, Warrington.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. ‡Sharp, T. B. French Walls, Birmingham.
1883. ‡Sharples, Charles H. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1896. ‡Shaw, Frank. Ellerslie, Aigburth-drive, Liverpool.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, E.C.
1889. *Shaw, Mrs. M. S., B.Sc. Halberton, near Tiverton, Devon.
1887. ‡Shaw, Saville, F.C.S. College of Science, Newcastle-upon-Tyne.
1883. *SHAW, W. N., M.A., F.R.S. Meteorological Office, Victoria-street, S.W.
1883. ‡Shaw, Mrs. W. N. Meteorological Office, Victoria-street, S.W.
1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
1878. ‡Shelford, William, M.Inst.C.E. 35A Great George-street, Westminster, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡SHENSTONE, W. A., F.R.S. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1890. ‡Shepherd, J. Care of J. Redmayne, Esq., Grove House, Headingley, Leeds.
1883. ‡Shepherd, James. Birkdale, Southport.
1900. §Sheppard, Thomas, F.G.S. 432 Holderness Road, Hull.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1896. §SHERRINGTON, C. S., M.D., F.R.S., Professor of Physiology in University College, Liverpool. 16 Grove-park, Liverpool.
1888. *Shickle, Rev. C. W., M.A. 5 Cavendish Crescent, Bath.
1886. ‡Shield, Arthur H. 35A Great George-street, S.W.
1892. ‡Shields, John, D.Sc., Ph.D. Dolphingston, Tranent, Scotland.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, E.C.
1867. ‡Shinn, William C. 39 Varden's-road, Clapham Junction, Surrey S.W.
1887. *SHIPLEY, ARTHUR E., M.A. Christ's College, Cambridge.
1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.
1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *SHOOLBRED, J. N., M.Inst.C.E. 47 Victoria-street, S.W.
1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, W.C.
1897. ‡Shore, Dr. Lewis E. St. John's College, Cambridge.

Year of Election

1875. ‡SHORE, THOMAS W., F.G.S. 105 Ritherdon-road, Upper Tooting, S.W.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. Heathfield, Alleyn Park, Dulwich, S.E.
1897. ‡Shortt, Professor Adam, M.A. Queen's University, Kingston, Ontario, Canada.
1889. ‡Sibley, Walter K., B.A., M.B. 8 Duke Street-mansions, Grosvenor-square, W.
1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1877. *Sidebotham, Joseph Watson. Merlewood, Bowdon, Cheshire.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *SIEMENS, ALEXANDER, M.Inst.C.E. 7 Airlie-gardens, Campden Hill, W.
1878. ‡SIGERSON, Professor GEORGE, M.D., F.L.S., M.R.I.A. 3 Clare street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1898. ‡Simmons, Henry. Kingsland House, Whiteladies-road, Clifton, Bristol.
1862. ‡Simms, James. 138 Fleet-street, E.C.
1874. ‡Simms, William. Upper Queen-street, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, W.
1847. ‡SIMON, Sir JOHN, K.C.B., M.D., D.C.L., F.R.S. 40 Kensington-square, W.
1893. ‡*Simpson, A. H., F.R.Met.Soc. Attenborough, Nottinghamshire.*
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. ‡Simpson, Byron R. 7 York-road, Birkdale, Southport.
1887. ‡Simpson, F. Estacion Central, Buenos Ayres.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S. 9 Barton-street, West Kensington, W.
1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, W.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
1896. *Simpson, W., F.G.S. The Gables, Halifax.
1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1870. *Sinclair, W. P. Rivelyn, Prince's Park, Liverpool.
1897. §§Sinnott, James. Bank of England-chambers, 12 Broad-street, Bristol.
1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892. ‡Sisley, Richard, M.D. 11 York-street, Portman-square, W.
1879. ‡*Skertchly, Sydney B. J. 3 Loughborough-terrace, Carshalton, Surrey.*
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1898. §§Skinner, Sidney. Cromwell House, Trumpington, Cambridgeshire.
1892. ‡Skinner, William. 35 George-square, Edinburgh.
1888. §SKRINE, H. D., J.P., D.L. Claverton Manor, Bath.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1884. ‡Slattery, James W. 9 Stephen's-green, Dublin.

Year of Election.

1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S. 65 Pembroke-road, Clifton, Bristol.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1887.§§Small, Evan W., M.A., B.Sc., F.G.S. The Mount, Radbourne-street, Derby.
1887. §Small, William. Lincoln-circus, The Park, Nottingham.
1885. ‡Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William, LL.D. Nunholme, Dowanhill, Glasgow.
1898. ‡Smeeth, W. F., M.A., F.G.S. Mysore, India.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. ‡Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1892. ‡*Smith, Adam Gillies, F.R.S.E. 35 Drumsheugh-gardens, Edinburgh.*
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. The University, Chicago, Illinois, U.S.A.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1872. *SMITH, BASIL WOODD, F.R.A.S. Branch Hill Lodge, Hampstead Heath, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Madras.
1865. ‡*Smith, David, F.R.A.S. 40 Bennett's-hill, Birmingham.*
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1900. §Smith, E. J. Grange House, Westgate Hill, Bradford.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. ‡Smith, E. Wythe. 66 College-street, Chelsea, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1897. ‡Smith, Sir Frank. 54 King-street East, Toronto, Canada.
1885. ‡Smith, Rev. G. A., M.A. 21 Sardinia-terrace, Glasgow.
1897. ‡Smith, G. Elliot, M.D. St. John's College, Cambridge.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 4 Harcourt-buildings, Inner Temple, E.C.
1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1883. ‡Smith, M. Holroyd. Royal Insurance Buildings, Crossley-street, Halifax.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1885. ‡SMITH, ROBERT H., Assoc.M.Inst.C.E. 53 Victoria-street, S.W.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1873. ‡Smith, Sir Swire. Lowfield, Keighley, Yorksh

Year of Election.

1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1894. §Smith, T. Walrond. 14 Calverley-park, Tunbridge Wells.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, Gower-street, W.C.
1896. *Smith, Rev. W. Hodson. 31 Esplanade-gardens, Scarborough.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton Down, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡Smithells, Arthur, B.Sc., Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1882. ‡Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1883. ‡Smyth, Rev. Christopher. Firwood, Chalford, Stroud.
1857. *Smyth, John, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *Snape, H. Lloyd, D.Sc., Ph.D., F.C.S., Professor of Chemistry in University College, Aberystwith.
1888. ‡*Snell, Albion T. Brightside, Salusbury Road, Brondesbury, N.W.*
1878. §Snell, H. Saxon. 22 Southampton-buildings, W.C.
1889. ‡Snell, W. H. Lancaster Lodge, Amersham Road, Putney, S.W.
1898. §Snook, Miss L. B. V. 13 Clare-road, Cotham, Bristol.
1879. *Sollas, W. J., M.A., D.Sc., F.R.S., F.R.S.E., F.G.S., Professor of Geology in the University of Oxford. 169 Woodstock-road, Oxford.
1892. *Somervail, Alexander. The Museum, Torquay.
1900. §Somerville, Professor W. 3 Adams Road, Cambridge.
1859. *Sorby, H. Clifton, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Ranmoor, Sheffield.
1892. ‡*Sorley, James, F.R.S.E. 18 Magdala-crescent, Edinburgh.*
1888. ‡Sorley, Professor W. R. The University, Cambridge.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1887. §Sowerbutts, Eli, F.R.G.S. 16 St. Mary's Parsonage, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1890. ‡Spark, F. R. 29 Hyde-terrace, Leeds.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1887. ‡Spencer, F. M. Fernhill, Knutsford.
1884. ‡Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newbiggin House, Kenton, Newcastle-upon-Tyne.
1891. *Spencer, Richard Evans. The Old House, Llandaff.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, N.
1894. ‡Spiers, A. H. Newton College, South Devon.
1864. *Spiller, John, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode, W. Hugh, F.C.S. 107 Sloane-street, S.W.
1854. *Sprague, Thomas Bond, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.

Year of Election.

1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, E.C.
1884. *Spruce, Samuel, F.G.S. Beech House, Albert Road, Tamworth.
1897. §Squire, W. Stevens, Ph.D. Clarendon House, 30 St. John's Wood Park, N.W.
1888. *Stacy, J. Sargeant. Hemel Hempstead.
1897. ‡Stafford, Joseph. Morrisburg, Ontario, Canada.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1892. ‡Stanfield, Richard, Assoc.M.Inst.C.E., F.R.S.E., Professor of Engineering in the Heriot Watt College, Edinburgh. 49 Mayfield-road, Edinburgh.
1883. *Stanford, Edward, jun., F.R.G.S. Thornbury, Bromley, Kent.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, S.E.
1894. *STANSFIELD, ALFRED, D.Sc. Royal College of Science, S.W.
1900 §Stansfield, H., B.Sc. Municipal Technical School, Blackburn.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1899. ‡STARLING, E. H., M.D., F.R.S., Professor of Physiology in University College, London. 8 Park-square West, N.W.
1876. ‡Starling, John Henry, F.C.S. 32 Craven-street, Strand, W.C
1899. §Statham, William. The Redings, Totteridge, Herts.
1898. ‡Stather, J. W., F.G.S. 16 Louis-street, Hull.
Staveley, T. K. Ripon, Yorkshire.
1894. ‡Stavert, Rev. W. J., M.A. Burnsall Rectory, Skipton-in-Craven, Yorkshire.
1873. *Stead, Charles. Red Barns, Freshfield, Liverpool.
1900. *Stead, J. E. Laboratory and Assay Office, Middlesborough.
1881. ‡Stead, W. H. Orchard-place, Blackwall, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1892. *STEBBING, Rev. THOMAS R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896. *Stebbing, W. P. D., F.G.S. 169 Gloucester-terrace, W.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1879. *STEPHENSON, Sir HENRY, J.P. The Glen, Sheffield.
1880. *Stevens, J. Edward, LL.B. Le Mayals, Blackpyl, R.S.O.
1900. §STEVENS, FREDERICK. Town Clerk's Office, Bradford.
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *STEVENSON, JAMES C. Westoe, South Shields.
1890. *Steward, Rev. Charles J., F.R.M.S. The Cedars, Anglesea-road, Ipswich.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Murtle, Aberdeen.
1864. ‡STEWART, CHARLES, M.A., F.R.S., F.L.S., Hunterian Professor of Anatomy and Conservator of the Museum, Royal College of Surgeons, Lincoln's Inn Fields, W.C.
1892. ‡Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. 14 Windsor-terrace, Kelvinside, Glasgow.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.

Year of Election.

1892. ‡Stewart, Samuel. Knocknairn, Bagston, Greenock.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. ‡Stockdale, R. The Grammar School, Leeds.
1883. *STOCKER, W. N., M.A., Professor of Physics in the Royal Indian Engineering College. Cooper's Hill, Staines.
1898. ‡Stoddart, F. Wallis, F.I.C. Grafton Lodge, Sneyd Park, Bristol.
1845. *STOKES, Sir GEORGE GABRIEL, Bart., M.A., D.C.L., LL.D., D.Sc., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1898. *Stokes, Professor George J., M.A. Riversdale, Sunday's Well, Cork.
1887. ‡Stone, E. D., F.C.S. Rose Lea, Alderley Edge, Cheshire.
1899. *Stone, F. J. Radley College, Abingdon.
1888. ‡STONE, JOHN. 15 Royal-crescent, Bath.
1886. ‡Stone, Sir J. Benjamin, M.P. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, E.C.
76. ‡Stone, Octavius C., F.R.G.S. Rothbury House, Westcliff-gardens, Bournemouth.
1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
895. *Stoney, Miss Edith A. 8 Upper Hornsey Rise, N.
1878. *Stoney, G. Gerald. 7 Roxburgh-place, Heaton, Newcastle-upon-Tyne.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 8 Upper Hornsey Rise, N.
1876. §Stopes, Henry. 25 Denning-road, Hampstead, N.W.
1883. ‡Stopes, Mrs. 25 Denning-road, Hampstead, N.W.
1887. *Storey, H. L. Lancaster.
1884. §Storrs, George H. Gorse Hall, Stalybridge.
1888. *Stothert, Percy K. Keynsham Manor, Saltford, Bristol.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General SIR RICHARD, R.E., G.C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, W.
1881. ‡STRAHAN, AUBREY, M.A., F.G.S. Geological Museum, Jermyn-street, S.W.
1876. ‡*Strain, John.* 143 *West Regent Street, Glasgow.*
1863. ‡Straker, John. Wellington House, Durham.
1889. ‡*Straker, Captain Joseph. Dilston House, Riding Mill-on-Tyne.*
1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1898. ‡Strangeways, C. Fox. Leicester.
1881 ‡STRANGWAYS, C. FOX, F.G.S. Geological Museum, Jermyn-street, S.W.
1889. ‡Streatfeild, H. S., F.G.S. Ryhope, near Sunderland.
1879. ‡Strickland, Sir Charles W., Bart., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1898. *Strong, W. M. 3 Champion Park, Denmark Hill, S.E.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the College of Science, Newcastle-upon-Tyne.

Year of Election.

1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. 5 Prince's-square, W.
1892. ‡Stuart, Hon. Morton Gray, M.A., F.G.S. 2 Belford Park, Edinburgh.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1893. ‡Stubbs, Arthur G. Sherwood Rise, Nottingham.
1896. ‡Stubbs, Miss. Torrisholme, Aigburth-drive, Sefton Park, Liverpool.
1885. ‡Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1897. ‡Stupart, R. F. The Observatory, Toronto, Canada.
1879. *Styring, Robert. 64 Crescent-road, Sheffield.
1891. *Sudborough, J. J., Ph.D., B.Sc. University College, Nottingham.
1898. §Sully, T. N. Avalon House, Priory-road, Tyndall's Park, Clifton, Bristol.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, E.
1888. ‡Sunderland, John E. Bark House, Hatherlow, Stockport.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. ‡Sutherland, James B. 10 Windsor-street, Edinburgh.
1884 ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1898. §Sutton, William, M.D. 6 Camden-crescent, Dover.
1891. ‡Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1881. §SWAN, JOSEPH WILSON, M.A., F.R.S. 58 Holland-park, W.
1897. §Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1887. §SWINBURNE, JAMES, M.Inst.C.E. 82 Victoria-street, S.W.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1887. *Swindells, Rupert, F.R.G.S. 22 Oxford Road, Birkdale, Southport.
1890. ‡SWINHOE, Colonel C., F.L.S. Avenue House, Oxford.
1891. ‡Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1895. ‡Sykes, E. R. 3 Gray's Inn-place, W.C.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, 64 Elmbourne-road, Tooting Common, S.W.
1896. *Sykes, Mark L., F.R.M.S. 19 Manor-street, Ardwick, Manchester.
1887. *Sykes, T. H. Cringle House, Cheadle, Cheshire.
1893. ‡Symes, Rev. J. E., M.A. 70 Redcliffe-crescent, Nottingham.
1870. ‡SYMES, RICHARD GLASCOTT, M.A., F.G.S., Geological Survey of Scotland. Sheriff Court-buildings, Edinburgh.
1885. ‡SYMINGTON, JOHNSON, M.D. Queen's College, Belfast.
1881. **Symington, Thomas. Wardie House, Edinburgh.*
1855. *SYMONS, WILLIAM. Dragon House, Bilbrook, Washford, Taunton.
1886. ‡Symons, W. H., M.D. (Brux.), M.R.C.P., F.I.C. Guildhall, Bath.

1896. §Tabor, J. M. Holmwood, Haringay Park, Crouch End, N.
1898. ‡Tagart, Francis. 199 Queen's-gate, S.W.

Year of
Election.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, Forfarshire.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1894. ‡Takakusu, Jyun, B.A. 17 Worcester-terrace, Oxford.
1893. ‡*Talbot, Herbert, M.I.E.E. 19 Addison-villas, Addison-street, Nottingham.*
1891. ‡Tamblyn, James. Glan Llynvi, Maesteg, Bridgend.
1890. ‡TANNER, H. W. LLOYD, M.A., F.R.S., Professor of Mathematics and Astronomy in University College, Cardiff.
1897. ‡Tanner, Professor J. H. Ithaca, New York, U.S.A.
1892. *Tansley, Arthur G. University College, W.C.
1883. *Tapscott, R. Lethbridge, Assoc.M.Inst.C.E., F.G.S., F.R.A.S. 62 Croxteth-road, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. Broadhayes, Dean Park, Bournemouth.
1857. *Tate, Alexander. Rantalard, Whitehouse, Belfast.
1893. ‡Tate, George, Ph.D. College of Chemistry, Duke-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1898. §§Taylor, Lieut.-Colonel G. L. Le M. 6 College-lawn, Cheltenham.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. ‡Taylor, George Spratt. 13 Queen's-terrace, St. John's Wood, N.W.
1881. *Taylor, H. A. 69 Addison-road, Kensington, W.
1884. *TAYLOR, H. M., M.A., F.R.S. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1887. ‡TAYLOR, Rev. Canon ISAAC, D.D. Settrington Rectory, York.
1861. *Taylor, John, M.Inst.C.E., F.G.S. 32 Bruton-street, W.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1899. §§Taylor, Robert H., M.Inst.C.E. 5 Maison Dieu-road, Dover.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡*Taylor, Rev. S. B., M.A. Whixley Hall, York.*
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1900. §Taylor, T. H. Yorkshire College, Leeds.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1895. ‡Taylor, W. A., M.A., F.R.S.E. Royal Scottish Geographical Society, Edinburgh.
1893. ‡Taylor, W. F. Bhootan, Whitehorse-road, Croydon, Surrey.
1894. *Taylor, W. W. 30 Banbury-road, Oxford.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡TEALE, THOMAS PRIDGIN, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡TEALL, J. J. H., M.A., F.R.S., F.G.S. 28 Jermyn-street, S.W.
1898. §Tebb, Robert Palmer. Enderfield, Chislehurst, Kent.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. The Nash, near Worcester.
1880. ‡TEMPLE, The Right Hon. Sir RICHARD, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.S., F.R.G.S. Athenæum Club, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1894. ‡Terras, J. A., B.Sc. 40 Findhorn-place, Edinburgh.
1882. ‡Terrill, William. 42 St. George's-terrace, Swansea.
1896. *Terry, Rev. T. R., M.A., F.R.A.S. The Rectory, East Ilsley, Newbury, Berkshire.

Year of Election.

1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *THANE, GEORGE DANCER, Professor of Anatomy in University College, Gower-street, W.C. Hemmet, St. John's Road, Harrow.
1889. ‡Thetford, The Right Rev. A. T. Lloyd, Bishop of, D.D. North Creake Rectory, Fakenham, Norfolk.
1885. ‡Thin, Dr. George. 22 Queen Anne-street, W.
1871. ‡*Thin, James. 7 Rillbank-terrace, Edinburgh.*
1871. ‡THISELTON-DYER, Sir W. T., K.C.M.G., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. Royal Gardens, Kew.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1891. *Thomas, Miss Clara. Penurrig, Builth.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891. ‡Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol
1881. ‡THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. 86 Breakspear's-road, Brockley, S.E.
1880. *Thomas, Joseph William, F.C.S. 2 Hampstead Hill-mansions, N.W.
1899. *Thomas, Mrs. J. W. 2 Hampstead Hill-mansions, N.W.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1898. ‡Thomas, Rev. U. Bristol School Board, Guildhall, Bristol.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. ‡Thomason, Yeoville. 9 Observatory-gardens, Kensington, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1891. *Thompson, Beeby, F.C.S., F.G.S. 55 Victoria-road, Northampton.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.
1885. ‡Thompson, D'Arcy W., B.A., C.B., Professor of Zoology in University College, Dundee.
1896. *Thompson, Edward P. Whitchurch, Salop.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1870. ‡THOMPSON, Sir HENRY, Bart. 35 Wimpole-street, W.
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.
1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.
1883. *THOMPSON, ISAAC COOKE, F.L.S., F.R.M.S. 53 Croxteth-road, Liverpool.
1897. ‡Thompson, J. Barclay. 37 St. Giles's, Oxford.
1891. ‡Thompson, J. Tatham, M.B. 23 Charles-street, Cardiff.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Cheshire.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.

Year of Election.

1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S., Principal and Professor of Physics in the City and Guilds of London Technical College, Finsbury, E.C.
1883. *Thompson, T. H. Redlynch House, Green Walk, Bowdon, Cheshire.
1896. *THOMPSON, W. H., M.D., Professor of Physiology in Queen's College, Belfast.
1896. ‡Thompson, W. P. 6 Lord-street, Liverpool.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1894. ‡THOMSON, ARTHUR, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1876. ‡*Thomson, James R. Mount Blow, Dalmuir, Glasgow.*
1891. ‡Thomson, John. 70A Grosvenor-street, W.
1896. ‡Thomson, John. 3 Derwent-square, Stonycroft, Liverpool.
1890. §THOMSON, Professor J. ARTHUR, M.A., F.R.S.E. Castleton House, Old Aberdeen.
1883. ‡THOMSON, J. J., M.A., D.Sc., F.R.S., Professor of Experimental Physics in the University of Cambridge. 6 Scrope-terrace, Cambridge.
1871. *THOMSON, JOHN MILLAR, LL.D., F.R.S., V.P.C.S., Professor of Chemistry in King's College, London. 85 Addison-road, W.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1897. ‡Thorburn, James, M.D. Toronto, Canada.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Sir Thomas. Dundee.
1898. §Thornton, W. M. The Durham College of Science, Newcastle-on-Tyne.
1883. ‡Thorowgood, Samuel. Castle-square, Brighton.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. Undercliffe, Holmfirth.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1898. §Thorpe, Jocelyn Field, Ph.D. Owens College, Manchester.
1871. ‡THORPE, T. E., C.B., Ph.D., LL.D., F.R.S., F.R.S.E., Pres.C.S., Principal of the Government Laboratories, Clement's Inn-passage, W.C.
1883. §Threlfall, Henry Singleton, J.P. 1 London-street, Southport.
1899. §THRELFALL, RICHARD, M.A., F.R.S. 259 Hagley-road, Birmingham.
1896. §Thrift, William Edward. 80 Grosvenor-square, Rathmines, Dublin.
1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. Tudor House, Richmond Green, Surrey.
1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.
1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S., Professor of Chemistry in the Royal College of Science, South Kensington, London. 9 Ladbroke-gardens, W.
1873. ‡Tilghman, B. C. Philadelphia, U.S.A.
1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. ‡Tillyard, Mrs. Fordfield, Cambridge.
1865. ‡Timmins, Samuel, J.P., F.S.A. Spring Hill, Arley, Coventry.
1896. §Timmis, Thomas Sutton. Cleveley, Allerton, Yorkshire.
1899. §Tims, H. W. Marett, M.D., F.L.S. 19 Lyndewode Road, Cambridge.

Year of Election.

1900. §Tocher, J. F., F.I.C. 5 Chapel Street, Peterhead, N.B.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, S.E.
1891. ‡Todd, Richard Rees. Portuguese Consulate, Cardiff.
1897. ‡Todhunter, James. 85 Wellesley-street, Toronto, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.
1896. ‡Toms, Frederick. 1 Ambleside-avenue, Streatham, S.W.
1887. ‡Tonge, James, F.G.S. Woodbine House, West Houghton, Bolton.
1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, S.W.
1875. ‡Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. St. Mary's, Stoke Bishop, Bristol.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *Trail, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.
1883. ‡Traill, A., M.D., LL.D. Ballylough, Bushmills, Ireland.
1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1868. ‡Traquair, Ramsay H., M.D., LL.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.
1891. ‡Trayes, Valentine. Maindell Hall, Newport, Monmouthshire.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1887. *Trench-Gascoigne, Mrs. F. R. Parlington, Aberford, Leeds.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1884. ‡Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1871. ‡Trimen, Roland, M.A., F.R.S., F.L.S., F.Z.S. Water Hall, St. Aldate's, Oxford.
1860. §Tristram, Rev. Henry Baker, D.D., LL.D., F.R.S., Canon of Durham. The College, Durham.
1884. *Trotter Alexander Pelham. 8 Richmond Terrace, Whitehall, S.W.
1885. §Trotter, Coutts, F.G.S., F.R.G.S. 10 Randolph-crescent, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *Trouton, Frederick T., M.A., D.Sc., F.R.S. Trinity College, Dublin.
1898. §Trow, Albert Howard. Glanhafren, Penarth.
1896. §Truell, Henry Pomeroy, M.B., F.R.C.S.I. Clonmannon, Ashford, Co. Wicklow.
1885. *Tubby, A. H., F.R.C.S. 25 Weymouth-street, Portland-place, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
1871. ‡Tuke, Sir J. Batty, M.D., M.P. Cupar, Fifeshire.
1887. ‡*Tuke, W. C.* 29 *Princess-street, Manchester.*
1883. ‡Tupper, The Hon. Sir Charles, Bart., G.C.M.G., C.B. Ottawa Canada.
1892. ‡Turnbull, Alexander R. Ormiston House, Hawick.

Year of Election.

1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1896. ‡*Turner, Alfred. Elmswood Hall, Aigburgh, Liverpool.*
1893. §Turner, Dawson, M.B. 37 George-square, Edinburgh.
1882. ‡Turner, G. S. Pitcombe, Winchester-road, Southampton.
1883. ‡Turner, Mrs. G. S. Pitcombe, Winchester-road, Southampton.
1894. *Turner, H. H., M.A., B.Sc., F.R.S., F.R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.
1886. *Turner, Thomas, A.R.S.M., F.C.S., F.I.C. Ravenhurst, Rowley Park, Stafford.
1863. *Turner, Sir William, K.C.B., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in the University of Edinburgh. (President.) 6 Eton-terrace, Edinburgh.
1893. ‡Turney, Sir John, J.P. Alexandra Park, Nottingham.
1890. *Turpin, G. S., M.A., D.Sc. School House, Swansea.
1886. *Twigg, G. H. 56 Claremont-road, Handsworth, Birmingham.
1898. §§Twiggs, H. W. 65 Victoria-street, Bristol.
1899. §Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1888. ‡Tyack, Llewelyn Newton. University College, Bristol.
1882. ‡*Tyer, Edward. Horneck,* 16 *Fitzjohn's-avenue, Hampstead, N.W.*
1865. §Tylor, Edward Burnett, D.C.L., LL.D., F.R.S., Professor of Anthropology, and Keeper of the University Museum, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.
1897. ‡Tyrrell, J. B., M.A., B.Sc. Ottawa, Canada.
1861. **Tysoe, John. Heald-road, Bowdon, near Manchester.*

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1888. ‡Underhill, H. M. 7 High-street, Oxford.
1886. ‡Underhill, Thomas, M.D. West Bromwich.
1885. §Unwin, Howard. 1 Newton-grove, Bedford Park, Chiswick.
1883. §Unwin, John. Eastcliffe Lodge, Southport.
1876. *Unwin, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institution of the City and Guilds of London Institute. 7 Palace-gate Mansions, Kensington, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡Upward, Alfred. 150 Holland-road, W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1898. ‡Usher, Thomas. 3 Elmgrove-road, Cotham, Bristol.
1880. ‡Ussher, W. A. E., F.G.S. 28 Jermyn-street, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. 38 Charles-street, Cardiff.
1896. ‡Vacher, Francis. 7 Shrewsbury-road, Birkenhead.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.
1884. ‡Van Horne, Sir W. C., K.C.M.G. Dorchester-street West, Montreal, Canada.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
1886. ‡Vardy, Rev A. R., M.A. King Edward's School, Birmingham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, N.
1865. *Varley, S. Alfred. Arrow Works, Jackson Road, Holloway, N.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, N.W.
1869. ‡Varwell, P. Alphington-street, Exeter.

Year of Election.

1884. ‡Vasey, Charles. 112 Cambridge-gardens, W.
1895. §Vaughan, D. T. Gwynne. Howry Hall, Llandrindod, Radnorshire.
1887. *VAUGHAN, His Eminence Cardinal. Carlisle-place, Westminster, S.W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §VELEY, V. H., M.A., F.R.S., F.C.S. 20 Bradmore-road, Oxford.
1873. *VERNEY, Sir EDMUND H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1883. ‡VERNON, H. H., M.D. York-road, Birkdale, Southport.
1896. *Vernon, Thomas T. Wyborne Gate, Birkdale, Southport.
1896. *Vernon, William. Tean Hurst, Tean, Stoke-upon-Trent.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.
1890. *Villamil, Lieut.-Colonel R. de, R.E. Care of Messrs. Cox & Co., 16 Charing Cross, S.W.
1899. *VINCENT, SWALE, M.B. Physiological Laboratory, University College, Cardiff.
1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1891. ‡Vivian, Stephen. Llantrisant.

1886. *Wackrill, Samuel Thomas, J.P. 38 Portland Street, Leamington.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1900. §Waddington, Dr. C. E. 2 Marlborough Road, Manningham, Bradford.
1890. ‡Wadsworth, G. H. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T. Arnold House, Bass Street, Derby.
1900. §Wagstaff, C. J. L., B.A. 8 Highfield Place, Manningham, Bradford.
1896. ‡*Wailes, Miss Ellen. Woodmead, Groombridge, Sussex.*
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.
1886. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1892. ‡*Walcot, John. 50 Northumberland-street, Edinburgh.*
1884. ‡Waldstein, Professor C., M.A., Ph.D. King's College, Cambridge.
1891. ‡Wales, H. T. Pontypridd.
1891. ‡Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1894. ‡WALFORD, EDWIN A., F.G.S. West Bar, Banbury.
1882. *Walkden, Samuel. Downside, Whitchurch, Tavistock.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1893. §Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent.
1890. §Walker, A. Tannett. The Elms, Weetwood, Leeds.
1897. *WALKER, B. E., F.G.S. Canadian Bank of Commerce, Toronto.
1883. ‡Walker, Mrs. Emma. 13 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
1891. §Walker, Frederick W. Tannett. Carr Manor, Meanwood, Leeds.
1897. §Walker, George Blake. Tankersley Grange, near Barnsley.
1894. *WALKER, G. T., M.A. Trinity College, Cambridge.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1896. ‡Walker, Horace. Belvidere-road, Prince's Park, Liverpool.
1890. ‡Walker, Dr. James. 8 Windsor-terrace, Dundee.
1894. *Walker, James, M.A. 30 Norham-gardens, Oxford.

Year of Election.

1866. *WALKER, J. FRANCIS, M.A., F.G.S., F.L.S. 45 Bootham, York.
1886. *Walker, Major Philip Billingsley. 16 Llandaff Street, Waverley, Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, S.E.
1888. ‡Walker, Sydney F. 195 Severn-road, Cardiff.
1887. ‡Walker, T. A. 15 Great George-street, S.W.
1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1895. §WALKER, WILLIAM G., A.M.Inst.C.E. 47 Victoria-street, S.W.
1896. §Walker, Colonel William Hall, M.P. Gateacre, Liverpool.
1896. ‡Walker, W. J. D. Lawrencetown, Co. Down, Ireland.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. Corfe View, Parkstone, Dorset.
1897. ‡Wallace, Chancellor. Victoria University, Toronto, Canada.
1892. ‡Wallace, Robert W. 14 Frederick-street, Edinburgh.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. Weston Lodge, 16 Grove End-road, N.W.
1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.
1895. ‡WALLIS, E. WHITE, F.S.S. Sanitary Institute, Parkes Museum, Margaret-street, W.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth, F.S.A. Chevening, Montague-road, Edgbaston, Birmingham.
1894. *WALMISLEY, A. T., M.Inst.C.E. Engineer's Office, Dover Harbour.
1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
1883. ‡*Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.*
1895. §WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1887. ‡WARD, A. W., M.A., Litt.D. Master of Peterhouse, Cambridge.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡WARD, H. MARSHALL, D.Sc., F.R.S., F.L.S., Professor of Botany, University of Cambridge. New Museums, Cambridge.
1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, J.P., F.S.A. Lenoxvale, Belfast.
1887. ‡WARD, JOHN, F.G.S. 23 Stafford-street, Longton, Staffordshire.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. Red House, Ravensbourne Park, Catford, S.E.
1884. *Ward, John William. Newstead, Halifax.
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Staffordshire.
1884. ‡Wardwell, George J. 31 Grove-street, Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Standard Underground Cable Co., 16th-street, Pittsburg, Pennsylvania, U.S.A.
1878. §WARINGTON, ROBERT, F.R.S., F.C.S. High Bank, Harpenden, St. Albans, Herts.
1882. ‡*Warner, F. I., F.L.S. 20 Hyde Street, Winchester.*
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1896. ‡*Warr, A. F. 4 Livingstone-drive North, Liverpool.*
1896. ‡Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.

Year of Election.

1875. ‡*Warren, Algernon. Downgate, Portishead.*
1887. ‡WARREN, Major-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. Athenæum Club, S.W.
1898. ‡Warrington, Arthur W. University College, Aberystwith.
1893. ‡Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *Waterhouse, Major-General J. Oak Lodge, Court-road, Eltham, Kent.
1870. ‡Waters, A. T. H., M.D. 60 Bedford-street, Liverpool.
1900. §Waterston, David. 16 Merchison Terrace, Edinburgh.
1892. ‡Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1887. ‡*Watkin, F. W. 46 Auriol-road, West Kensington, W.*
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1886. *Watson, C. J. Alton Cottage, Botteville Road, Acock's Green, Birmingham.
1883. ‡Watson, C. Knight, M.A. 49 Bedford-square, W.C.
1892. §Watson, G., Assoc.M.Inst.C.E. 21 Springfield-mount, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡WATSON, Rev. Henry W., D.Sc., F.R.S. The Rectory, Berkeswell, Coventry.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. P.O. Box 317, Johannesburg, South Africa.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 16 St. Mary's-road, Bayswater, W.
1894. *WATSON, W., B.Sc. 7 Upper Cheyne-row, S.W.
1892. §Watson, William, M.D. Waverley House, Slateford, Midlothian.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Steelfield Hall, Gosforth, Cumberland.
1882. ‡*Watt, Alexander. 19 Brompton-avenue, Sefton Park, Liverpool.*
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E. Ashley-avenue, Belfast.
1888. ‡WATTS, B. H. 10 Rivers-street, Bath.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Canon Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Little Don Waterworks, Langsett, near Penistone.
1896. ‡Watts, W. H. Elm Hall, Wavertree, Liverpool.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, and Carrholme, Stackhouse, near Settle.
1883. *WATTS, W. W., M.A., Sec. G.S., Assistant Professor of Geology in the Mason University College, Birmingham; Holm Wood, Bracebridge Road, Sutton Coldfield.
1891. ‡Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1890. ‡*Webb, Sidney. 4 Park-village East, N.W.*
1886. ‡WEBBER, Major-General C. E., C.B., M.Inst.C.E. 17 Egerton-gardens, S.W.
1891. §Webber, Thomas. Kensington Villa, 6 Salisbury-road, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. 48 Westendstrasse, Karlsruhe.

Year of Election.

1889. ‡Weeks, John G. Bedlington.
1890. *Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany in Owens College, Manchester.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, S.W.
1894. §§Weld, Miss. Conal More, Norham-gardens, Oxford.
1876. *Weldon, Professor W. F. R., M.A., F.R.S., F.L.S. The Museum Oxford.
1880. *Weldon, Mrs. Merton Lea, Oxford.
1897. ‡Welford, A. B., M.B. Woodstock, Ontario, Canada.
1881. §Wellcome, Henry S. Snow Hill Buildings, E.C.
1879. §Wells, Charles A., A.I.E.E. 219 High-street, Lewes.
1881. §Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1894. ‡Wells, J. G. Selwood House, Shobnall-street, Burton-on-Trent.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1881. *Wenlock, The Right Hon. Lord. Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1898. ‡West, Charles D. Imperial University, Tokyo, Japan.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1900. §West, William, F.L.S. 26 Woodville Terrace, Horton Lane, Bradford.
1897. ‡Western, Alfred E. 36 Lancaster-gate, W.
1882. *Westlake, Ernest, F.G.S. Vale Lodge, Vale of Health, Hampstead, N.W.
1882. ‡Westlake, Richard. Portswood, Southampton.
1882. ‡Wethered, Edward B., F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1900. §Wethey, E. R., M.A., F.R.G.S. 5 Cunliffe Villas, Manningham, Bradford.
1885. *Wharton, Admiral Sir W. J. L., K.C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. Florys, Prince's-road, Wimbledon Park, Surrey.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.
1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. 18 Frognal, Hampstead, N.W.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1893. *Whetham, W. C. D., M.A. Trinity College, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *Whidborne, Rev. George Ferris, M.A., F.G.S. The Priory, Westbury-on-Trym, near Bristol.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
1874. ‡Whitaker, Henry, M.D. Fortwilliam Terrace, Belfast.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
1859. *Whitaker, William, B.A., F.R.S., F.G.S. Freda, Campden-road, Croydon.

Year of Election.

1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1897. §Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva. 47 Clanricarde-gardens, W.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1898. ‡White, George. Clare-street House, Bristol.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. Balruddery, Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡*White, John Forbes.* 311 *Union-street, Aberdeen.*
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. 6 Southwell-gardens, S.W.
1895. ‡White, Philip J., M.B., Professor of Zoology in University College, Bangor, North Wales.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1898. ‡White, Samuel. Clare-street House, Bristol.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 66 Cambridge-gardens, Notting Hill, W.
1883. *White, Mrs. 66 Cambridge-gardens, Notting Hill, W.
1886. *White, William. The Ruskin Museum, Sheffield.
1897. *WHITE, Sir W. H., K.C.B., F.R.S. The Admiralty, Whitehall, S.W.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 80 Beeches-road, West Bromwich.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1852. ‡*Whitla, Valentine. Beneden, Belfast.*
1900. §Whitley, E. N. Heath Royde, Halifax.
1891. §Whitmell, Charles T., M.A., B.Sc. Invermay, Headingley, Leeds.
1896. §Whitney, Colonel C. A. The Grange, Fulwood Park, Liverpool.
1897. §WHITTAKER, E. T., M.A. Trinity College, Cambridge.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 11 Poplar-road, Ramsgate.
1887 ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. 1 Berkeley-square, Clifton, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, W.
1892. §Whyte, Peter, M.Inst.C.E. 3 Clifton-terrace, Edinburgh.
1897. ‡Wickett, M., Ph.D. 339 Berkeley-street, Toronto, Canada.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.
1865. ‡Wiggin, Sir H., Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1896. ‡Wigglesworth, J. County Asylum, Rainhill, Liverpool.
1883. ‡Wigglesworth, Mrs. 23 Westbourne-grove, Scarborough.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1889. *Wilberforce, Professor L. R., M.A. University College, Liverpool.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *WILDE, HENRY, D.Sc., F.R.S. The Hurst, Alderley Edge, Cheshire.
1896. ‡Wildermann, Meyer. 22 Park-crescent, Oxford.
1887. ‡*Wilkinson, C. H. Slaithwaite, near Huddersfield.*
1900. §Wilkinson, J. B. Dudley Hill, Bradford.
1892. ‡Wilkinson, Rev. J. Frome., M.A. Barley Rectory, Royston, Herts.
1886. *Wilkinson, J. H. Elmhurst Hall, Lichfield.

Year of Election.

1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. Vale Bank, Knutsford, Cheshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡Willans, J. W. Kirkstall, Leeds.
1872. ‡WILLETT, HENRY. Arnold House, Brighton.
1894. ‡Willey, Arthur. New Museums, Cambridge.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, W.
1887. ‡Williams, Sir E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1883. ‡Williams, Rev. H. Alban, M.A. Christ Church, Oxford.
1888. ‡Williams, James. Bladud Villa, Entry Hill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. Lingfield Grange, Branksome Park, Bournemouth.
1883. *Williams, Mrs. J. Davies. 3 Lord Street West, Southport.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke Vale, Clifton, Bristol.
1875. *Williams, M. B. Killay House, Killay, R.S.O.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. 28 Compayne-gardens, West Hampstead, London, N.W.
1883. ‡Williams, T. H. 21 Strand-street, Liverpool.
1877. *WILLIAMS, W. CARLETON, F.C.S. University College, Sheffield.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., D.C.L., F.R.S., High Pitfold, Haslemere.
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1895. ‡WILLINK, W. 14 Castle-street, Liverpool.
1895. ‡Willis, John C., M.A., Director of the Royal Botanical Gardens, Ceylon.
1896.§§WILLISON, J. S. Toronto, Canada.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, S.W.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1898. §Wills, H. H. Barley Wood, Wrington, R.S.O., Somerset.
1899. §Willson, George. The Rosary, Wendover, Tring.
1899. §Willson, Mrs. George. The Rosary, Wendover, Tring.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. Free Church Manse, North Queensferry.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1894. *Wilson, Charles J., F.I.C., F.C.S. 14 Old Queen-street, Westminster, S.W.
1874. ‡WILSON, Major-General Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. The Athenæum Club, S.W.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1900. *Wilson, Duncan R. Menethorpe, Malton.

Year of Election.

1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 99 Albany-street, N.W.
1875. ‡WILSON, GEORGE FERGUSSON, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1895. ‡Wilson, Gregg. The University, Edinburgh.
1883. *Wilson, Henry, M.A. Farnborough Lodge, Farnborough, R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall Gate, Doncaster.
1865. ‡WILSON, Ven. Archdeacon JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1896. ‡*Wilson, John H., D.Sc., F.R.S.E., Professor of Botany, Yorkshire College, Leeds.*
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1861. ‡*Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.*
1892. §Wilson, T. Stacey, M.D. Wyddrington, Edgbaston, Birmingham.
1887. §Wilson, W., jun. Hillocks of Terpersie, by Alford, Aberdeenshire.
1871. *WILSON, WILLIAM E., F.R.S. Daramona House, Streete, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., D.Sc., F.G.S., F.L.S., F.R.A.S. 25 Granville-park, Lewisham, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. ‡WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., Professor of Anatomy in Mason College, Birmingham.
1887. ‡*Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.*
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1888. ‡WODEHOUSE, Right Hon. E. R., M.P. 56 Chester-square, S.W.
1875. ‡WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1898. ‡Wollaston, G. H Clifton College, Bristol.
1884. ‡Womack, Frederick, M.A., B.Sc., Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. Bedford College, Baker-street, W.
1883. ‡Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John Street, Adelphi, W.C., and 16 Leinster Square, Bayswater, W.
1883. *Wood, J. H. 21 Westbourne Road, Birkdale.
1893. ‡Wood, Joseph T. 29 Muster's-road, West Bridgeford, Nottinghamshire.
1883. ‡Wood, Mrs. Mary. Care of E. P. Sherwood, Esq. Holmes Villa, Rotherham.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorkshire.

Year of Election.

1872. ‡Wood, William Robert. Carlisle House, Brighton.
1845. *Wood, Rev. William Spicer, M.A., D.D. Waldington, Combe Park, Bath.
1863. *WOODALL, JOHN WOODALL, M.A., F.G.S. 5 Queen's-mansions, Victoria-street, S.W.
1884. ‡Woodbury, C. J. H. 31 Milk-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, N.W.
1896. §WOODHEAD, Professor G. SIMS, M.D. Pathological Laboratory, Cambridge.
1888. *Woodiwiss, Mrs. Alfred. Weston Manor, Birkdale, Lancashire.
1872. ‡*Woodman, James. 26 Albany-villas, Hove, Sussex.*
*WOODS, EDWARD, M.Inst.C.E. 8 Victoria-street, Westminster, S.W.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
1887. *WOODWARD, ARTHUR SMITH, LL.D., F.L.S., F.G.S., Assistant Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1869. *WOODWARD, C. J., B.Sc., F.G.S. 97 Harborne-road, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, S.W.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, S.W.
1870. ‡WOODWARD, HORACE B., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1894. *Woodward, John Harold. 13 Queen Anne's-gate, Westminster, S.W.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. *Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.
1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1856. ‡Woolley, Thomas Smith. South Collingham, Newark.
1874. ‡*Workman, Charles. Ceara, Windsor, Belfast.*
1899. §§Workman, Thomas. Craigdarragh, Co. Down.
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Old Swinford, Stourbridge.
1856. ‡*Worthy, George S. 2 Arlington Terrace, Mornington Crescent, Hampstead Road, N.W.*
1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1896. ‡Wrench, Edward M., F.R.C.S. Park Lodge, Bastow.
1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1890. ‡Wright, Dr. C. J. Virginia-road, Leeds.
1857. ‡WRIGHT, E. PERCEVAL, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. ‡WRIGHT, Professor R. RAMSAY, M.A., B.Sc. University College Toronto, Canada.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.

Year of Election.

1871. ‡WRIGHTSON, Sir THOMAS, Bart., M.P., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1898. ‡Wrong, Professor George M. The University, Toronto, Canada.
1897. ‡Wyld, Frederick. 127 St. George-street, Toronto, Canada.
1883. §§Wyllie, Andrew. Sandown, Southport.
1885. ‡Wyness, James D., M.D. 349 Union-street, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Plas-yn-Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.
1899. §§WYNNE, W. P., D.Sc., F.R.S. 10 Selwood-terrace, South Kensington, S.W.

1875. ‡Yabbicom, Thomas Henry. 23 Oakfield-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, E.
1883. ‡Yates, James. Public Library, Leeds.
1896. ‡Yates, Rev. S. A. Thompson. 43 Phillimore-gardens, S.W.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, S.E.
1886. *YOUNG, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Sir Frederick, K.C.M.G. 5 Queensberry-place, S.W.
1894. *Young, George, Ph.D. University College, Sheffield.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. ‡YOUNG, JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1896. ‡Young, J. Denholm. 88 Canning-street, Liverpool.
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1886. §Young, R. Fisher. New Barnet, Herts.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S., Professor of Chemistry in University College, Bristol. 10 Windsor-terrace, Clifton, Bristol.
1887. ‡Young, Sydney. 29 Mark-lane, E.C.
1890. ‡Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1868. ‡Youngs, John. Richmond Hill, Norwich.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, D.C., U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18).
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, U.S.A. (3909, Locust-street).
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1894. Professor F. Beilstein. 8th Line, No. 17, St. Petersburg.
1894. Professor E. van Beneden. 50 quai des Pêcheurs, Liége, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 4, Germany.
1892. Professor M. Bertrand. 75 rue de Vaugirard, Paris.
1894. Deputy Surgeon-General J. S. Billings. 40 Lafayette Place, New York, U.S.A.
1893. Professor Christian Bohr. Bredgade 62, Copenhagen, Denmark.
1880. Professor Ludwig Boltzmann. IX/I. Türkenstrasse 3, Vienna.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, U.S.A.
1884. Professor H. P. Bowditch, M.D. Harvard Medical School, Boston, Massachusetts, U.S.A.
1890. Professor Dr. L. Brentano. Maximilian-platz 1, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Kristiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale University, New Haven, Conn., U.S.A.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, U.S.A.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna.
1887. Hofrath Dr. H. Caro. C. 8, No. 9, Mannheim.
1894. Emile Cartailhac. 5 Rue de la Chaîne, Toulouse, France.
1861. Professor Dr. J. Victor Carus. Universitätstrasse 15, Leipzig.
1894. Dr. A. Chauveau. Rue Cuvier 7, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, U.S.A.
1873. Professor Guido Cora. Via Goito 2, Rome.
1880. Professor Cornu. Rue de Grenelle 9, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. 5 Piazza S. Pietro in Vincoli, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, D.C., U.S.A.
1872. Professor G. Dewalque. 17 rue de la Paix, Liége, Belgium.

Year of Election.

1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. 5 Quai Marcellis, Liége, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1894. Professor T. W. W. Engelmann, D.C.L. Neue Wilhelmstrasse 15, Berlin, N.W.
1892. Professor Léo Errera. 38 Rue de la Loi, Brussels.
1874. Dr. W. Feddersen. Carolinenstrasse 9, Leipzig.
1886. Dr. Otto Finsch. Leiden, Netherlands.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W. 48.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1894. Professor Léon Fredericq. Rue de Pitteurs 20, Liége, Belgium.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague.
1892. Professor Dr. Gustav Fritsch. Dorotheen Strasse 35, Berlin.
1881. Professor C. M. Gariel. 6 rue Edouard Détaille, Paris.
1866. Dr. Gaudry. 7 bis rue des Saints Pères, Paris.
1884. Professor J. Willard Gibbs. Yale University, New Haven, Conn., U.S.A.
1884. Professor Wolcott Gibbs. Newport, Rhode Island, U.S.A.
1889. G. K. Gilbert. United States Geological Survey, Washington, D.C., U.S.A.
1892. Daniel C. Gilman. Johns Hopkins University, Baltimore, U.S.A.
1870. William Gilpin. Denver, Colorado, U.S.A.
1889. Professor Gustave Gilson. l'Université, Louvain.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, D.C., U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, Mass., U.S.A.
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
1887. Fr. von Hefner-Alteneck. Berlin.
1893. Professor Paul Heger. Rue de Drapiers 35, Brussels.
1894. Professor Ludimar Hermann. The University, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoologisches Institut, Alte Akademie, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, N.Y., U.S.A.
1887. Professor W. His. Königstrasse 22, Leipzig.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. The University, Utrecht, Netherlands.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, Rhode Island, U.S.A.
1884. Professor C. Loring Jackson. 6 Boylston Hall, Cambridge, Massachusetts, U.S.A.
1867. Dr. J. Janssen, LL.D. L'Observatoire, Meudon, Seine-et-Oise.
1876. Dr. W. J. Janssen. Villa Frisia, Aroza, Graubünden, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. 32 East Preston Street, Baltimore, U.S.A.
1887. Professor C. Julin. 151 rue de Frognée, Liége.
1876. Dr. Giuseppe Jung. 9 Via Borgonuovo, Milan.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tōkyō, Japan.

Year of Election.

1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 92, Wilmersdorf, bei Berlin.
1896. Dr. Kohlrausch. Physikalisch-technische Reichsanstalt, Charlottenburg, Berlin.
1856. Professor A. von Kölliker. Würzburg, Bavaria.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1887. Professor Dr. Arthur König. Physiological Institute, The University, Berlin, N.W.
1894. Maxime Kovalevsky. Beaulieu-sur-Mer, Alpes-Maritimes.
1887. Professor W. Krause. Knesebeckstrasse, 17/I, Charlottenburg, bei Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. The University, Bern, Switzerland.
1887. Professor A. Ladenburg. Kaiser Wilhelm Str. 108, Breslau.
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1894. Baron Osten-Sacken. Heidelberg.
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1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand, Belgium.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. 1333 F. Street, N.W., Washington, D.C., U.S.A.
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1887. Professor Georg Quincke. Hauptstrasse 47, Friederichsbau, Heidelberg.
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1887. Professor August Weismann. Freiburg-in-Breisgau, Baden.

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